DOCUMENT RESUME

ED 356 942 SE 053 004

AUTHOR	Nations, Jim, Comp.
TITLE	NASA/Aerospace Education Services Program. Classroom Activities.
INSTITUTION	National Aeronautics and Space Administration, Washington, D.C.; Oklahoma Univ., Norman.
PUB DATE	88
NOTE	90p.
PUB TYPE	Guides - Classroom Use - Instructional Materials (For Learner) (051) -- Guides - Classroom Use - Teaching Guides (For Teacher) (052)
EDRS PRICE	MF01/PC04 Plus Postage.
DESCRIPTORS	*Aerospace Education; Astronomy; Biology; Class Activities; Earth Science; Elementary Secondary Education; *Learning Activities; Manipulative Materials; Models; Physical Sciences; *Science Activities; *Science Education; Science Instruction; *Space Exploration; *Space Sciences
IDENTIFIERS	Hands on Science; *Rockets; Space Craft; Spacelab; Space Shuttle; Space Travel

ABSTRACT

This document consists of a collection of classroom activities as they appeared in the "Aviation and Space Education News" from 1988 to 1991. The 45 activities in the document are organized in the following sections: (1) Aeronautics; (2) Earth Science; (3) Space Science; (4) Life in Space; (5) Rockets; and (6) Models. Each activity is illustrated with black and white drawings and/or diagrams, and each write-up contains one or more of the following components: name of activity; subject (e.g., aeronautics, biology, robotics, etc.); topic; thumbnail description of activity; materials needed (usually easily available household objects or inexpensive store items); methods, procedures, or calculations required; and discussion. (PR)

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Classroom Activities

Compiled by Jim Nations, OSU

SE053004

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Classroom Activities

Hot Air Balloon

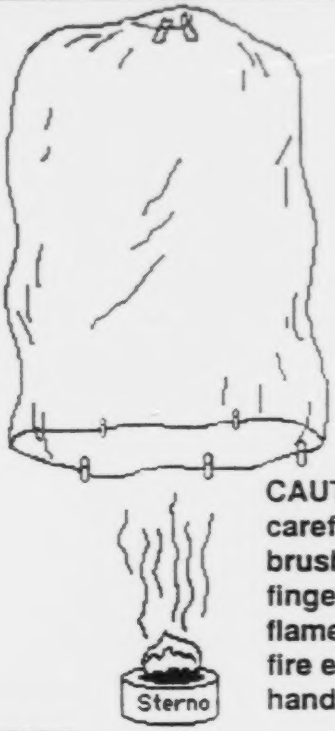
SUBJECT: Aeronautics
TOPIC: Lift
DESCRIPTION: An indoor hot air balloon made out of a plastic film dry cleaner bag.
CONTRIBUTED BY: Gregory Vogt (OSU)

MATERIALS:

Dry cleaner plastic film bag (select a bag with the thinnest possible plastic)
Several small paper clips
Cellophane tape
Heat source (Sterno, backpacker camp stove, etc.)
Matches

PROCEDURE:

1. Seal any openings and tears in the upper end of the bag with cellophane tape.
2. Attach several paper clips to the plastic around the lower opening. The number of paper clips to attach is determined by experimentation.
3. Light the Sterno or stove and spread the bag opening wide to capture the hot air rising from the flames while supporting the upper end with your hand. It is best to have assistance in keeping the bag open so that it does not melt.
4. When the bag is inflated with hot air, test its buoyancy by letting it go for a moment. If it rises quickly, stand back and let it fly otherwise continue heating it for a little while longer.
5. If the bag tips over and spills its hot air before it reaches the ceiling, add a few more paper clips to weigh down the bottom slightly. If the bag will not rise at all, remove a few clips.



CAUTION: Be careful not to brush clothes or fingers into the flames. Keep a fire extinguisher handy.

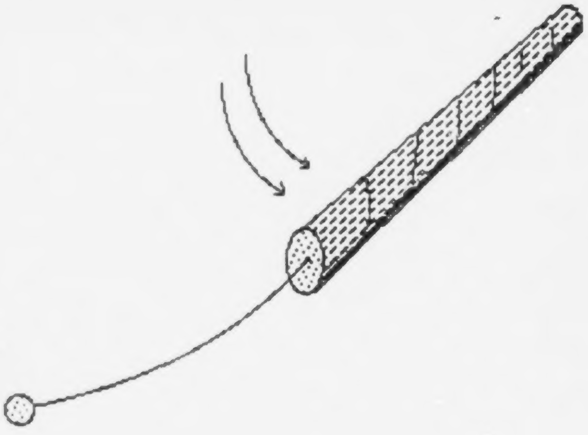
DISCUSSION:

Hot air is less dense than cold air. Heat accelerates the motion of the air molecules causing fewer molecules to occupy the same space as a much greater number of molecules do at a lower temperature. With fewer molecules, the hot air has less mass, and therefore is buoyant, in an equal volume of colder air.

Placing the dry cleaner bag over the heat source captures the hot air and forces out the cooler air in the bag. The bag becomes a mass of low-density air which floats upward in the higher denser air surrounding it. The paper clips are placed at the bottom of the bag to keep the open end downward in flight to prevent it from prematurely spilling the hot air and terminating the flight.

Classroom Activities

PING PONG BALL CURVES



SUBJECT: Aeronautics
TOPIC: Lift
DESCRIPTION: A ping pong ball is tossed with a rapid spin causing it to curve in flight.
CONTRIBUTED BY: *Demonstrations and Laboratory Experiences in The Science of Aeronautics*, Civil Aeronautics Administration and American Council on Education (1945)

MATERIALS:

Paper mailing tube of a greater diameter than a ping pong ball
1 sheet of medium sand paper
Ping pong ball
White glue
Ruler
Knife

METHOD:

1. Cut a 2 foot length from the mailing tube.

2. Roll up the sheet of sand paper, with the grit to the inside, into a tube. Spread white glue in several places and slide the sand paper into the mailing tube so that the sand paper is flush with one end. Let the glue dry.

PROCEDURE:

1. Practice throwing ping pong ball curves in an open place.

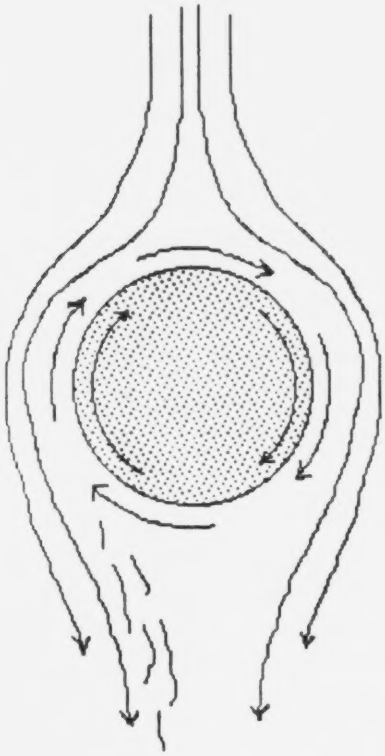
2. Hold the tube with your throwing hand at the end opposite the sand paper. Drop the ping pong ball in the tube.

3. Quickly swing the tube horizontally through the air. The ball will shoot out the tube and curve through the air as it flies forward.

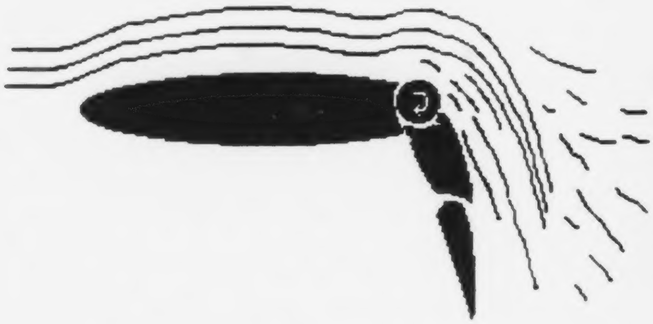
DISCUSSION:

The mailing tube makes it easy to achieve a "major league" curve pitch with a ping pong ball. As the ball is thrown from the tube, the ball rubs against the sand paper on the side of the tube from the direction the tube is moving. Friction from the sand paper on the ping pong ball causes it to spin rapidly in a clockwise direction for right-handed throws and counterclockwise for left handed throws.

As the ball spins, the surface friction of the ball with the surrounding air drags a thin layer of air with it. This is referred to as the *boundary layer*. At the same time the ball spins, it is moving forward. On one side of the ball, the boundary layer air is traveling in the same direction as the air stream that is flowing around the ball. On the other side, it is traveling in the opposite direction. (see figure 2) On the side of the ball where the air stream and boundary layer air are moving opposite to each other, there is a buildup of air pressure and turbulence. The buildup diverts the ball's flight and causes the ball to curve to the right for right-handed throws. Left-handed throws produce a curve to the left. A vertical throw causes the ball to loft upward.



A practical application for this curving effect is a rotating cylinder flap for an airplane wing. A rotating cylinder is mounted in the joint between a wing and its flaps. During low speed operation, the cylinder spins rapidly in the same direction as the air stream. Boundary layer air is bent downward over the steeply angled flap. This increases lift for the wings and delays the buildup of turbulence conditions that could lead to a stall. (see figure 3)



Classroom Activities

Musical Tube

SUBJECT: Aeronautics
TOPIC: Air Properties
DESCRIPTION: A whirling tube makes musical notes demonstrating the Bernoulli Theorem.
CONTRIBUTED BY: Gregory Vogt, OSU

MATERIALS:
Corrugated flexible plastic tube (Corrugated tubing is available from swimming pool supply stores. Ask for a piece about 1 meter long. Tubing is also available from toy stores under names such as Whirl-A-Tune™.)

METHOD:

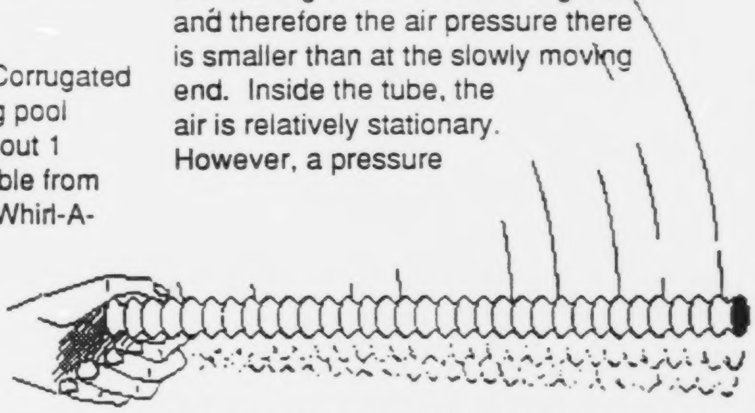
1. Hold the tube at one end and twirl the other end rapidly through the air. Make sure not to hit anything with the whirling end. A musical note will be produced.

2. Whirl the tube at different speeds and relate to the pitch of the sounds produced.

3. Plug the end of the tube in your hand with a cloth and spin the tube. Is a sound produced?

DISCUSSION:

The musical tube provides an audible demonstration of the Bernoulli Theorem. The free end of the tube moves through the air much more rapidly than the end in your hand. Consequently, the velocity of the air around the free end is much greater than the velocity around the end in your hand. Bernoulli's Theorem, in general terms, describes the relationship in a fluid between pressure and velocity. Where the velocity is greater, the pressure is smaller and vice versa. The velocity of the air around the moving end of the tube is greater and therefore the air pressure there is smaller than at the slowly moving end. Inside the tube, the air is relatively stationary. However, a pressure differential is created between the two ends and air flows from the slowly moving end to the fast moving end where it spills out. The tube's corrugations cause the air to vibrate as it travels from one end of the tube to the other. The vibration produces the musical note. When the tube is moving faster, the vibration frequency increases raising the pitch. When the tube is plugged, no air flows and the sound is stopped.



The musical tube can be used to demonstrate the same pressure changes that also take place around an airplane. By making air flow faster over the top of a wing than below it, a major share of aerodynamic lift is produced.

Classroom Activities

Flying Tube

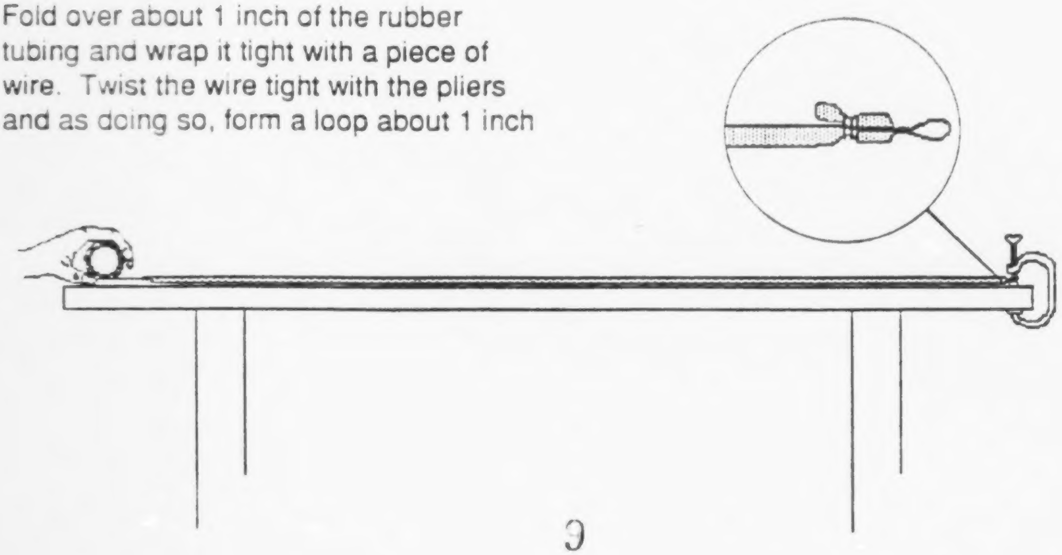
SUBJECT: Aeronautics
TOPIC: Circular airfoils
DESCRIPTION: A spinning paper tube generates lift as it travels forward.
CONTRIBUTED BY: Dale Bremmer, NASA HQ

MATERIALS and TOOLS:

Center tube from paper towel roll
5 feet of surgical rubber tubing
3 ft of cloth ribbon (do not use slippery ribbon)
2 ft of bell or iron wire
C-clamp
Pliers

METHOD

1. Fold over about 1 inch of the rubber tubing and wrap it tight with a piece of wire. Twist the wire tight with the pliers and as doing so, form a loop about 1 inch in diameter in the wire.
2. Attach one end of the ribbon to the other end of the rubber tub with a piece of wire. Twist the wire tight.
3. Slip the wire loop over the screw shaft of the C-clamp. Tighten the clamp to the end of a table.
4. Lay the tube and ribbon across the table. Place the paper tube on top of the ribbon at its free end and roll it up snugly in the ribbon.
5. While keeping the ribbon from slipping, pull the paper tube back to stretch the rubber tubing. Release the tube. The tube will be spun as the rubber tubing spins it at the same time. With enough speed and spin, the paper tube will lift off the table and may fly a loop through the air.

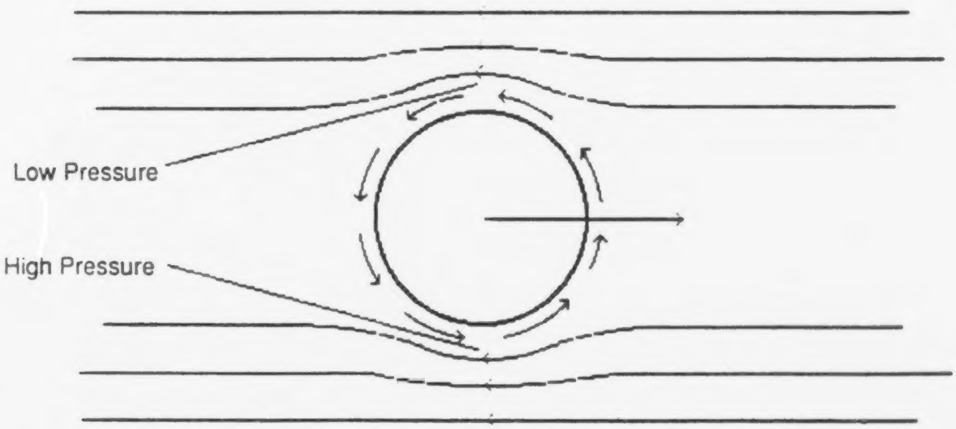


DISCUSSION

When the paper tube is released, two motions are imparted to it. The tube is pulled rapidly through the air and at the same time it is spun. The combinations of motions generate aerodynamic lift. When seen from the side, air is made to flow over and under the tube as the tube moves forward. The tube's surface experiences a small amount of friction with the air. As it spins, the friction drags air in contact with the tube's surface around with it (see the figure). On the top of the tube, the air being dragged around with the tube and the air flowing over the tube are traveling in the same direction. Below the tube, the air being dragged around the tube and the air flowing under it are traveling in opposite directions. There, the air piles up and creates a small zone of relatively high pressure. On top of the tube the pressure is lower. If the tube is moving fast enough through the air and spinning rapidly enough, the over versus under pressure difference will be greater than the weight of the tube. The tube will begin flying and it will do so as long as its air speed and rotation are maintained. This is aerodynamic lift.

Rotating airfoils have been added to the wings of some high-performance airplane wings to increase lift under certain flying conditions. At least one early airplane designer unsuccessfully tried to build a plane with rotating cylinders instead of wings (see the film "Aeronautical Oddities").

What do you think would happen if the paper tube were rotated in the opposite direction as it moved forward?



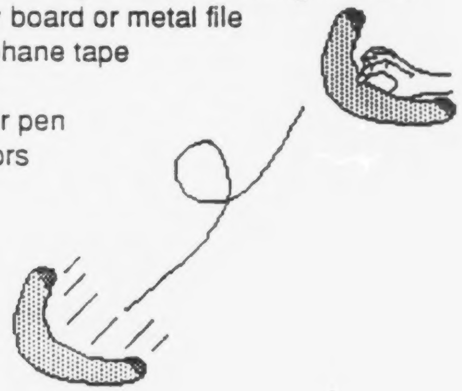
Classroom Activities

Flying Wing

SUBJECT: Aeronautics
TOPIC: Gliding flight
DESCRIPTION: An aerobatic flying wing is constructed from plastic foam trays obtainable from a supermarket.

CONTRIBUTED BY: Norm Poff (adapted from a design by Paul McIlrath.)

MATERIALS:
Plastic foam meat or pastry tray, about 10 inches long, from a supermarket
Sharp cutting knife and cutting surface
Emery board or metal file
Cellophane tape
Dime
Marker pen
Scissors



METHOD

1. Cut out and trace the Flying Wing pattern on the bottom of the foam tray. Position the pattern so that the shaded wing tips lay on one of the upturned edges of the tray. When cut out, the wing tips will have a permanent upward bend.
2. With the emery board or metal file, shape the upper surface of the Flying Wing into an airfoil. Use the cross-section diagrams as a guide for shaping.
3. Tape the dime to the underside of the wing so that it is positioned just forward of the center mark. It will probably be necessary to adjust the position of the dime a few times to get the best position for flight. The Flying Wing is ready for test flights.

BALANCING AND FLYING THE FLYING WING

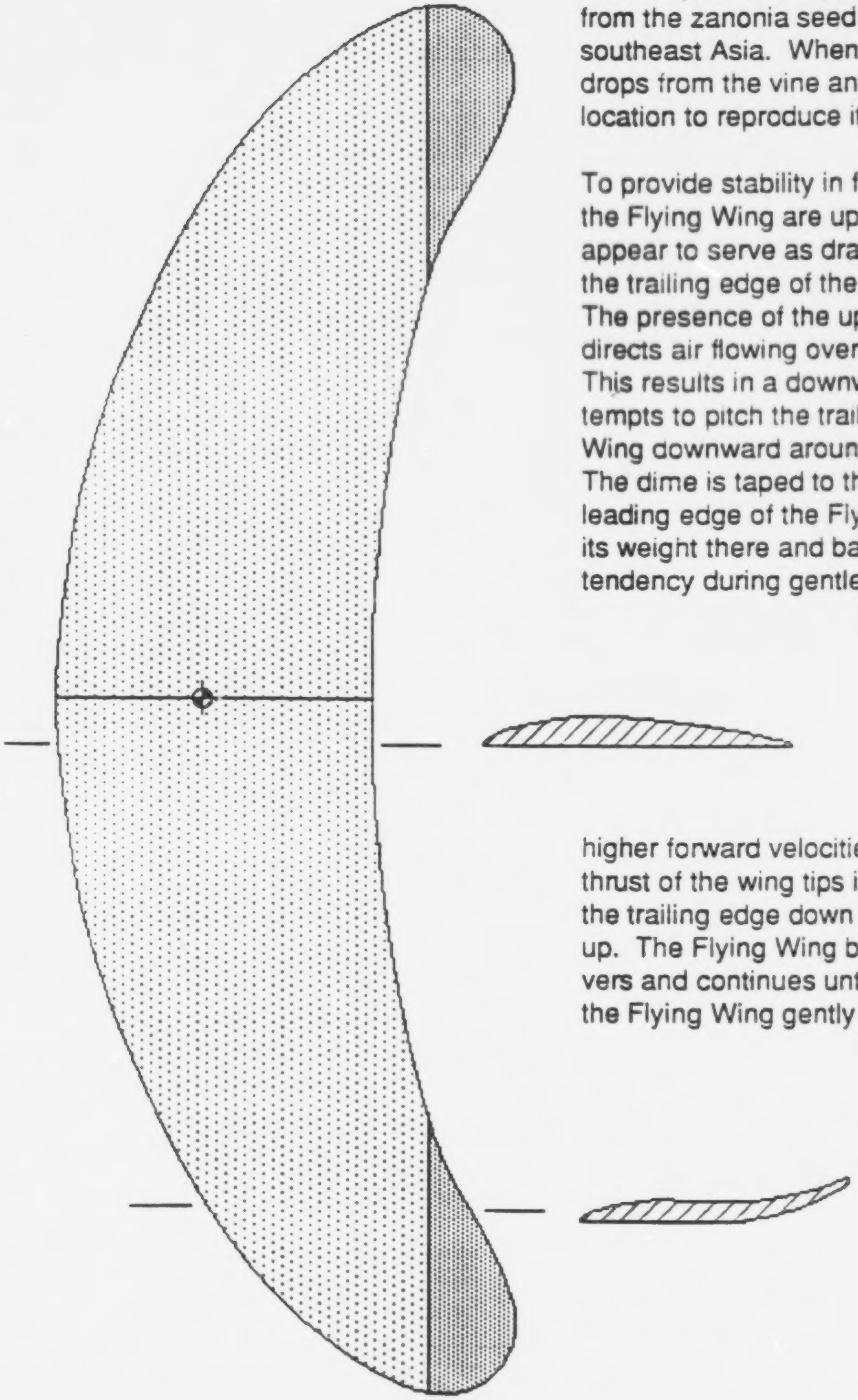
Go to an open area and hold the Flying Wing in your hand as shown in the diagram. Toss the wing gently straight forward. Observe the flight of the Flying Wing.

Flight Path	Correction
Flies straight and glides smoothly to the floor some distance away.	Don't mess with iit! It's ready.
Banks to the right.	Flatten the right wing tip bend slightly.
Banks to the left.	Flatten the left wing tip bend slightly.
Stalls.	Move the dime slightly forward.
Dives to the floor.	Move the dime slightly back.

DISCUSSION

The shape of the Flying Wing is adapted from the zanonia seed which is found in southeast Asia. When mature, the seed drops from the vine and glides to a new location to reproduce itself.

To provide stability in flight, the wing tips of the Flying Wing are upturned. These tips appear to serve as drag rudders that keep the trailing edge of the wing trailing in flight. The presence of the upturned wing tips also directs air flowing over the wing tips upward. This results in a downward thrust that attempts to pitch the trailing edge of the Flying Wing downward around its center of gravity. The dime is taped to the underside of the leading edge of the Flying Wing to increase its weight there and balance the pitching tendency during gentle, gliding flight. At higher forward velocities, the downward thrust of the wing tips is magnified, pitching the trailing edge down and the leading edge up. The Flying Wing begins looping maneuvers and continues until drag slows it and the Flying Wing gently glides to the ground.



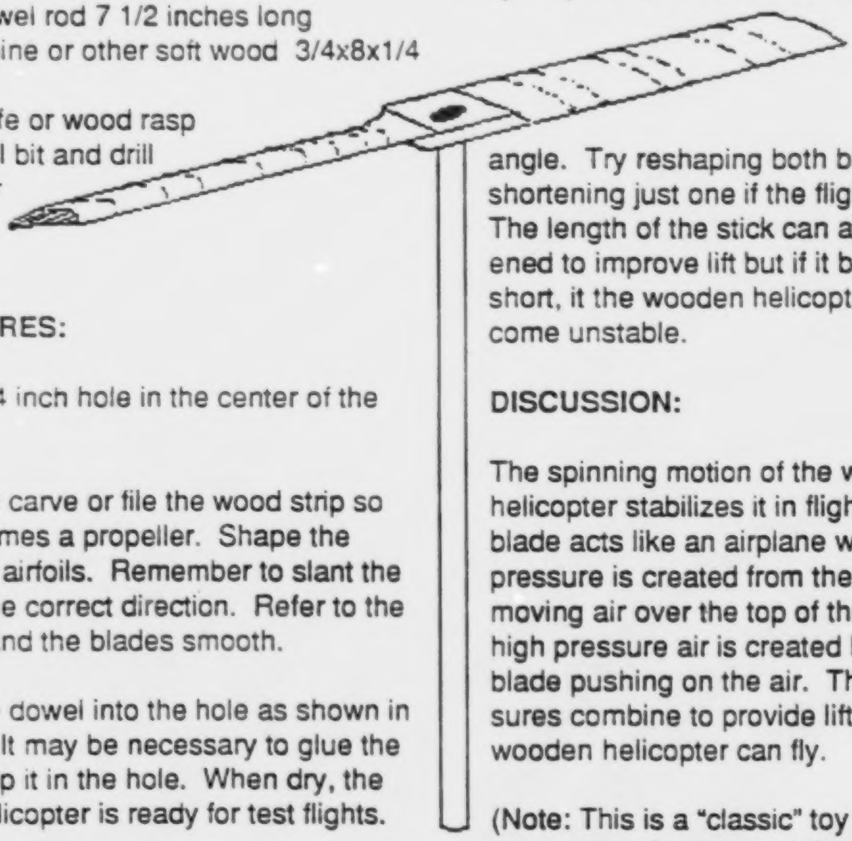
Classroom Activities

Wooden Helicopter

SUBJECT: Aeronautics
TOPIC: Propulsion
DESCRIPTION: Make two pieces of wood into a simple helicopter.
CONTRIBUTED BY: Gregory Vogt, OSU

MATERIALS and TOOLS:

1/4 inch dowel rod 7 1/2 inches long
1 piece of pine or other soft wood 3/4x8x1/4 inches
Carving knife or wood rasp
1/4 inch drill bit and drill
Sand paper
Glue
pencil



PROCEDURES:

1. Drill a 1/4 inch hole in the center of the strip.

2. Carefully carve or file the wood strip so that it becomes a propeller. Shape the blades into airfoils. Remember to slant the airfoils in the correct direction. Refer to the picture. Sand the blades smooth.

3. Push the dowel into the hole as shown in the figure. It may be necessary to glue the stick to keep it in the hole. When dry, the wooden helicopter is ready for test flights.

FLYING THE WOODEN HELICOPTER

Hold the stick between the palms of your hands with the propeller upward. Rapidly move your palms in opposite directions. The movement will spin the stick and the propeller. Let go of the stick and watch its flight. If the stick moves immediately downward and strikes your knuckles, reverse the directions of your hands. During a good flight, the stick will climb straight up and settle gently, with the stick end down, to the floor. If the flight is poor, check the blades. They may be too thick or not cut at a good angle. Try reshaping both blades or shortening just one if the flight is erratic. The length of the stick can also be shortened to improve lift but if it becomes too short, it the wooden helicopter will become unstable.

DISCUSSION:

The spinning motion of the wooden helicopter stabilizes it in flight. Each blade acts like an airplane wing. Low pressure is created from the rapidly moving air over the top of the blade and high pressure air is created below by the blade pushing on the air. The two pressures combine to provide lift so that the wooden helicopter can fly.

(Note: This is a "classic" toy from many years ago. A commercial version is sold under the name Puddle Jumper ™.

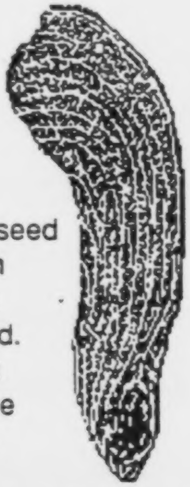
Classroom Activities

"Maple Seed" Helicopters

SUBJECT: Aeronautics
TOPIC: Helicopters
DESCRIPTION: Autorotating helicopters, based on the shape of maple seeds, are made from paper.
CONTRIBUTED BY: Gregory Vogt, OSU

MATERIALS:

Paper
Scissors
Paper clips



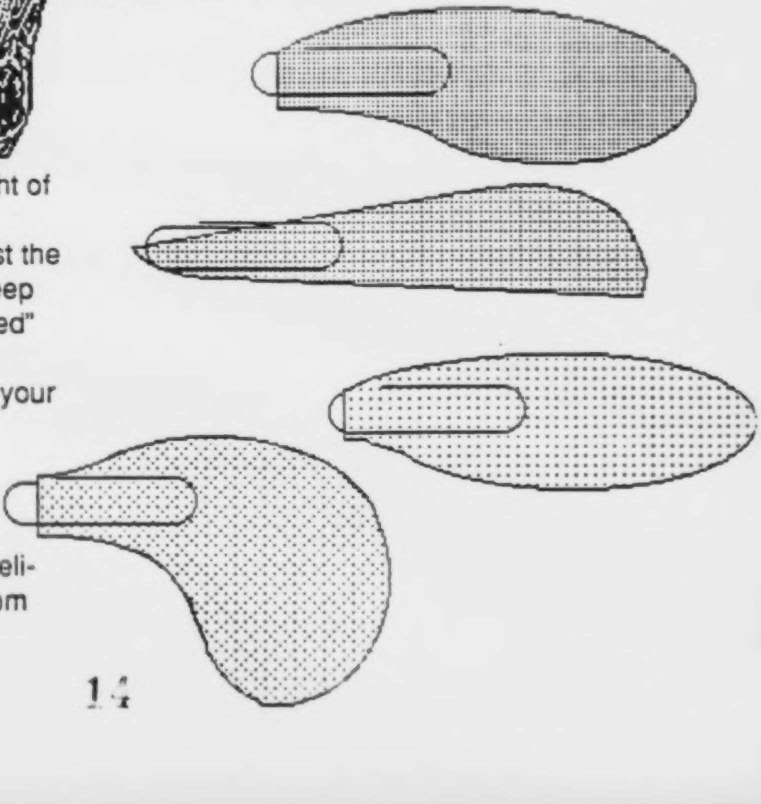
METHOD

1. Make copies of the maple seed patterns and derivatives on blank paper. Cut out each pattern and fold, if indicated.
2. Attach a paper clip to each design and slightly warp the paper to produce an airfoil shape.
3. Drop each "maple seed" from a height of at least 5 feet and watch its fall.
4. If the design fails to autorotate, adjust the position of the paper clip slightly. Keep adjusting the clip until the "maple seed" begins autorotating as it falls.
5. Experiment with different designs of your own making.

Discussion

Maple seeds are superb autorotating helicopters. They begin rotating almost from the moment they are released from the tree. Even seeds that are poorly shaped or badly damaged rotate with "ease."

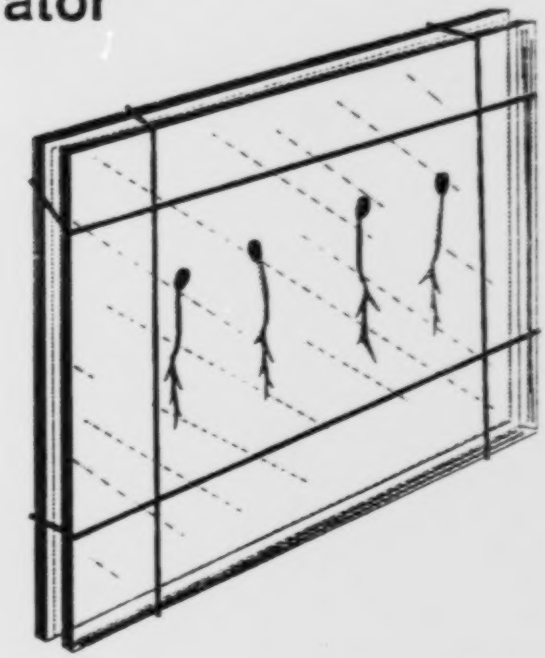
Autorotation takes place because of the asymmetrical nature of maple seeds (and of paper copies). The center of mass of the seed is shifted well to one end while its center of lift is approximately in the middle. In a complicated process, the forces at work, as the seed falls, combine to begin a circular rotation of the seed about its center of mass. The rotation actually inscribes a cone around the axis of fall. The shape of the cone will vary depending upon the aerodynamic qualities of the seed's blade (wing). A blade with minimal lift properties will inscribe a steep-side cone while a blade with strong lift properties will inscribe a very flattened cone.



Classroom Activities

Geotropism Demonstrator

Subject: Plant Tropisms
Topic: Geotropism
Description: Seeds are germinated in a transparent growth chamber and are later inverted to show geotropism.
Contributed By: Gregory Vogt, OSU



Materials: (per growth chamber)
2 Sheets of plastic window pane 6" by 6"
Paper towels
Garden seeds (beans, peas, radishes, etc.)
Dish pan or other tub
Scissors
Water
Rubber bands (4)
Emery paper (fine)

Procedure:

1. Smooth the edges of the plastic sheets with emery paper.
2. Cut 4 squares of paper towel 6" by 6" in size.
3. Lay down a sheet of glass. Place the towel squares on top of the panes. Place four seeds in a row across the middle of the towels about 1 inch apart from each other. Lay the second pane on top of the pile.
4. Secure the panes together by looping four rubber bands around them as shown in the illustration.
5. Stand the edges of the panes in the dish pan so that the seeds are arranged horizontally. Add about 1 inch of water to the tub and keep it filled to that level.
6. In a few days to a week or so, when stems and roots of the plants are about 1/2 to 1 inches long, turn the panes upside down to invert the plants. Observe new growth patterns over the next several days.

Discussion:
Due to capillary action and the absorbancy of the paper towels, water is carried up to the seeds to permit them to germinate. In response to the effects of gravity, the seedling's stems grow upward and the roots grow downward. By inverting the growth cell, the direction of gravity for the seedlings

Classroom Activities

Plant Centrifuge

Subject: Plant tropisms
Topic: Geotropism
Description: Plants grown in a shallow spinning dish respond to the apparent outward G-forces by leaning inward.
Contributed By: Gregory Vogt, OSU

Materials:

Old phonograph turntable
Shallow dish (pie tin or round glass baking dish)
Soil
Seeds (sunflower, corn, snap beans, or ?)

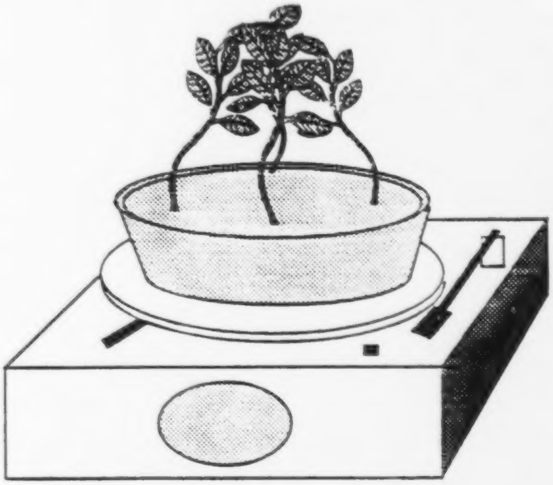
Procedure:

1. Place good potting soil in the pie tin or baking dish.

2. Poke holes in the soil at equal intervals around the perimeter of the tin or dish and plant two of each seed. Cover the seeds and water. (Caution: avoid overwatering because there is no place for excess water to go in such a shallow container.)

3. If you can remove the spindle of the turntable, do so. Otherwise, you will have to place several circles of cardboard over the spindle to raise the table surface above the top of the spindle. Several old records will work just as well.

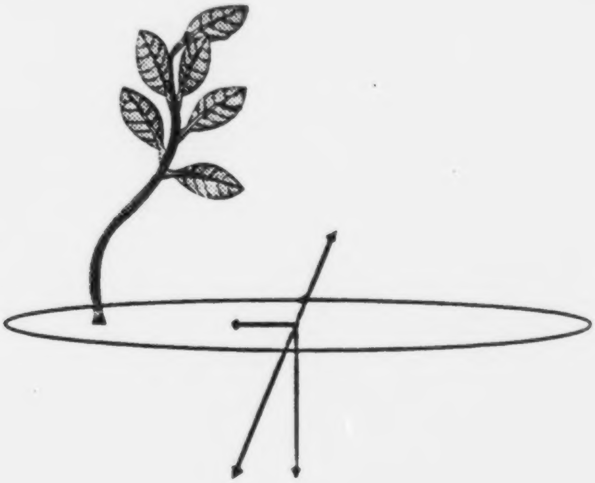
4. When the seedlings sprout several inches above the soil, observe their shapes. Place the tin or baking dish on the phonograph turntable and start the plants spinning at 33 and 1/3 rpm or 45 rpm.



5. Observe the seedlings over a period of several hours to see their response to the rotation.

Discussion:

Plant responses to gravity (geotropism) are thought to be the result of variable growth due to the distribution of growth hormones. Spinning the plants on a phonograph turntable simulates an additional pull of gravity to the outside of the circle. This gravity simulation is often incorrectly called "centrifugal force". (See discussion below.) The combination of the gravitational pull of Earth and the simulated gravity produces a resultant G-force at an outside angle to the vertical. (See the figure.) Growth hormones migrate towards the outside edges of the stems of each of the plants and accelerate the growth there. With slower growth on the inside edges of the stems and faster on the outside, the plants grow inward towards the center of the tin or dish. Eventually, this new direction of growth diminishes as the plant stems near the center. Movement during spinning is much less toward the center than at the outside edge, reducing the migration of the growth hormones.



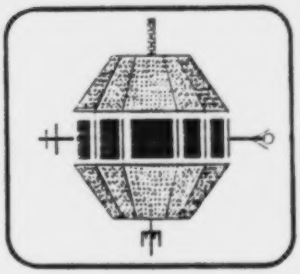
Plant growth experiments in space have shown that plant roots become "confused" by the weightless condition. Roots will actually grow up from the soil in the same direction as stems. Stems are usually not quite as effected as roots because growth lights in growing chambers attract stems and leaves towards them.

Designers of future space stations and manned interplanetary spacecraft will need to address geotropism in plants. Plants may be utilized for nutritional supplements, atmosphere regeneration, and general vehicle or station aesthetics.

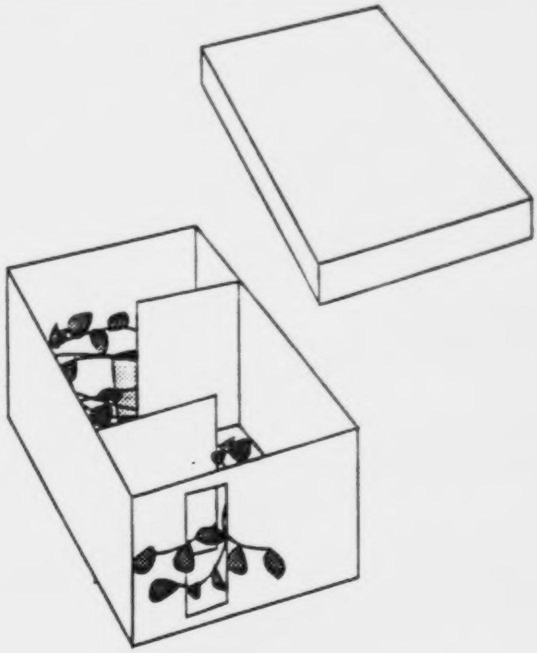
Centrifugal Force

Centrifugal force is a useful term for describing the apparent outward pull experienced when an object is spun at the end of a string. In spite of what is felt, the outward pull, centrifugal force, doesn't really exist. According to Isaac Newton's first law of motion, objects in motion travel in a straight line unless acted upon by an unbalanced force. This can easily be demonstrated by letting go of the string. Rather than flying outward, the object travels away at a tangent to the circular path it was traveling in before its release. The pull that is felt is actually an unbalanced force that continually changes the path of the object from a straight line to a circle. In otherwords, the holder of the string exerts an inward pull on the string to change the object's path. The object resists, with what is perceived as an outward pull, and tries to continue in a straight line. This conflict effects the plants growing in the dish. The plants try to travel in a straight line but are pulled into circular motion. Growth hormones, free to move through plant tissues, also try to travel in straight lines and migrate to the outer edges, causing uneven growth.

Classroom Activities



Phototropism Maze



SUBJECT: Biology
TOPIC: Photopism in green plants
DESCRIPTION: An enclosed "mouse maze" is used to demonstrate that plants will seek light.
CONTRIBUTED BY: Gregory Vogt, OSU

MATERIALS:
2 Cardboard boxes and lids used for copy machine paper
Large nails or masking tape
Sharp knife or heavy duty scissors
Sweet potato
Water glass
Toothpicks
Water

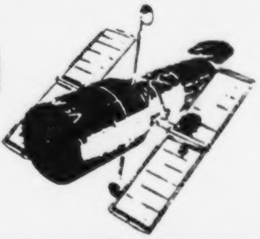
PROCEDURE:

1. Cut two or three light baffles from one of the two cardboard boxes. The baffles will be mounted inside the second box and should be tall enough to reach from the bottom of the second box to the lid and wide enough to stretch across from one side to just past the middle point.
2. Using large nails or masking tape, mount the baffles in the box as indicated in the diagram. If using nails, line place one edge of each baffle along the side of the second box. Push the nail through the box wall and into the corrugation of the baffle. Do the same from the bottom.
3. Cut a small light opening in one end of the box.
4. Push four toothpicks into a small sweet potato so they look somewhat like the spokes of a bicycle wheel. Set the potato in a glass. The toothpicks will keep the sweet potato from touching the bottom. Fill the glass with water so that the sweet potato's bottom is immersed. Keep the glass filled.
5. When the sweet potato begins sprouting small vines, place the glass in the far corner of the box away from the hole. Cover the box and place it in a location where it will not be disturbed and where sunlight or a strong room light will enter the hole.
6. Check on the plant periodically to make sure the water has not evaporated away. Study the growth of the vines.

DISCUSSION:

Green plants grow towards light in a process called phototropism. Through phototropism, plants maximize the amount of light energy reaching leaves for photosynthesis. Plants grown in orbiting spacecraft require light just as Earth-grown plants do. In space, however, plant growth is often confused because of the weightless condition of orbit deprives plants of gravity effects that normally cause stems and leaves to grow up and roots to grow down. Phototropism helps plants to partially alleviate the situation by directing leaf and stems growth towards light sources in growing chambers.

Classroom Activities



"Pollution" Hampers Your View

SUBJECT: Astronomy
TOPIC: Telescopic observations
DESCRIPTION: The atmosphere and its components filter light coming to Earth from space lessening the value of Earth-based telescopic observations and illustrating the need for orbital observatories.
CONTRIBUTED BY: James McMurtry, SSC

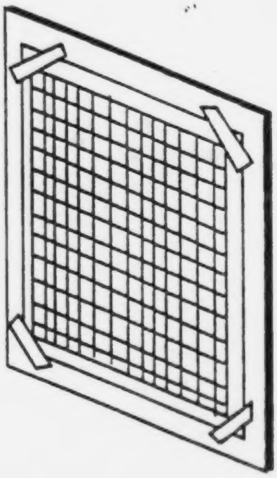
PARTICLE POLLUTION SAMPLER

MATERIALS:

- Clear Contact Paper (5X5 inches square)
- Graph paper (5X5 inches square, 1/2 inch grid)
- Cardboard (6X6 inches square)
- Cellophane tape
- Magnifying glass

PROCEDURES:

1. Tape the graph paper to the center of the card and tape the contact paper on top with the sticky side up. Do not remove the protective backing yet.
2. Place the pollution sampler outside on a flat surface preferably several feet above the ground. You may have to anchor the sampler if the air is windy. Remove the protective backing but retain it for later use.



3. After exposing the sampler to the outside for 24 hours, replace the protective backing and return the sampler to school.
4. Remove the backing again and using the magnifier, count the number of particles found in each of 10 randomly selected squares on the graph paper grid. Divide the total number of particles counted by 10 to get an average number.
5. Compare the average particle counts from several samplers to each other and to the locations where they were placed (proximity to farms, factories, freeways, etc.).

DISCUSSION:

Even on a clear night, many small particles are present in the atmosphere. Dust particles are lofted into the air by wind and other particles are produced as combustion products from cars, fire places, industry, volcanic eruptions, and a variety of other sources. These particles filter the light that comes through the atmosphere from space. In part to counteract the dust problem, large astronomical telescopes are placed on mountains away from cities. Still, very fine particles are present that hamper telescopic observations.

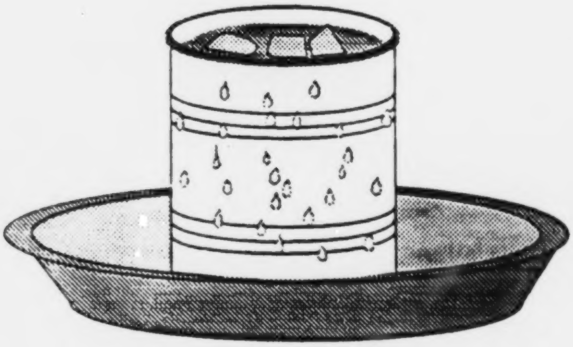
WATER IN THE AIR

MATERIALS:

Number 10 metal food can with lid removed
Pie tin
Ice
Water
Towel (optional)

PROCEDURES:

1. Fill the can with ice and water and place the can in the middle of the pie tin. You may wish to set the tin on a towel to protect the table surface below.
2. Observe the outside of the can for the next few hours.



DISCUSSION:

Water in the atmosphere produces haze and clouds which obscures telescope observations. Large astronomical telescopes are placed at high locations to get above much of the moisture in the air and secure clearer views of objects in space.

This demonstration reveals the presence of invisible water vapor in the classroom. The water vapor condenses on the outside of the cold metal of the can and collects in the pie tin below.

"CLEAR AIR"

MATERIALS:

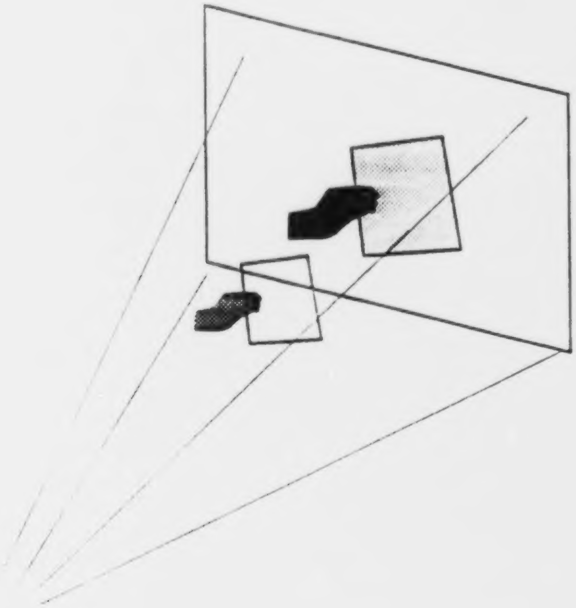
Small sheet of clean glass
Slide projector or uncovered light (bulb and fixture)
Projection screen
Dark room

PROCEDURES:

1. Show your students that the sheet of glass is "absolutely clear."
2. Darken the room and turn on the projector or light bulb.
3. Hold the clear glass between the light and screen. Observe the distinct shadow and dimness of the light that has passed through the glass.

DISCUSSION:

This demonstration provides an analogy of the light filtering effects of the gases in Earth's atmosphere. The shadow reveals the glass, like the gasses in the atmosphere, is not as clear as it would appear. Earth's atmosphere permits visible light to reach the surface of Earth, some of the ultraviolet and infrared radiations that come down from space, and most radio waves. However, most radiations coming to Earth from space, like x-rays and cosmic rays, are blocked by the atmosphere. Placing telescopes in space permits gathering a much wider range of radiations emitted from objects in space.



HEAT CURRENTS

MATERIALS:

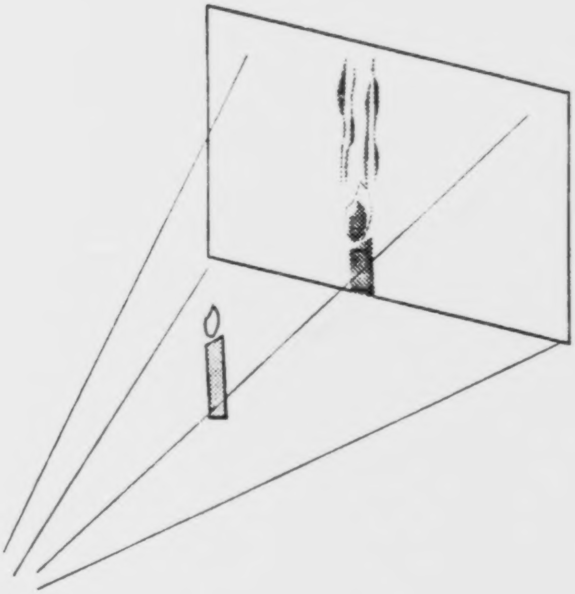
Candle or can of Sterno fuel
Matches
Slide projector or uncovered light bulb and fixture
Projection screen
Dark room

PROCEDURES:

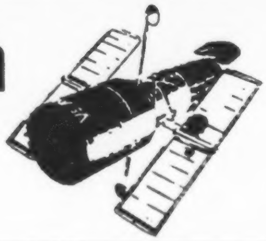
1. Darken the room and turn on the projector or light bulb.
2. Light the candle or Steno fuel and place it in between the light and the screen.
3. Stand back and observe the optical effects on the screen. (Air currents in the room interfere with this demonstration.

DISCUSSION:

Heat currents in the atmosphere cause the twinkling effect seen in starlight. Light rays from stars are refracted as they pass through cells (masses) of warm less dense air into cells of cooler more dense air. This caused the path the light rays traveled to bend slightly producing the twinkling effect. This movement causes serious problems with astronomical telescopes that are used for photography. Images of stars, which should be pin points, dance around on the photographic film and create fuzzy disks. Advance telescopes that use image sensing equipment and computer processing can negate the twinkling effect somewhat but the best way is to eliminate it entirely by orbiting telescopes above Earth.

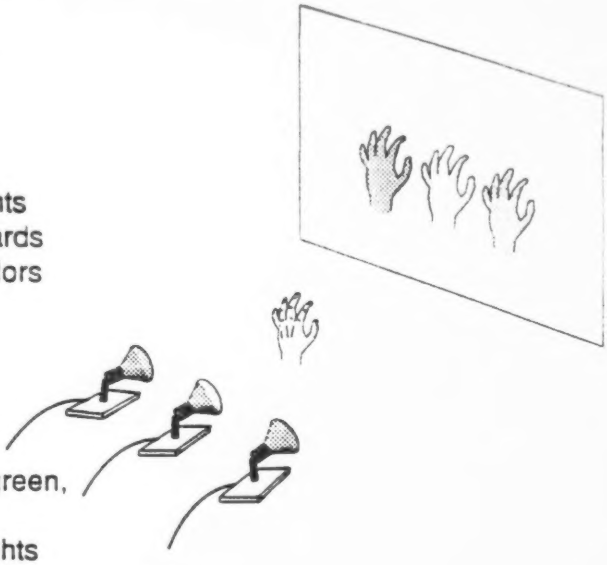


Classroom Activities



Colored Shadows

SUBJECT: Images from space
TOPIC: Colored images
DESCRIPTION: Three colored floodlights (red, green, and blue) are directed towards a screen to produce a wide range of colors ranging from black to white.



MATERIALS:

Indoor outdoor floodlights (red, green, and blue)
Adjustable fixtures to hold the lights
Projection screen
Dark room

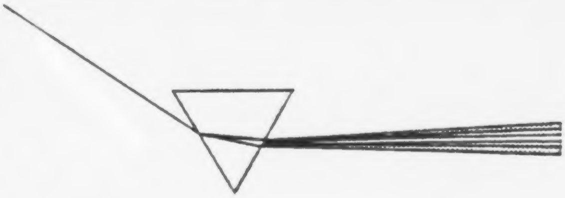
PROCEDURE:

1. Prior to class, set up the three floodlights in a row at a distance of about 10 feet from the projection screen so that they each point to the center of the screen. The lights should be spaced about 3 to 4 feet apart from each other. When properly aimed, the three lights should blend to produce a nearly white light falling on the screen. It may be necessary to move one or more lights closer to or farther away from the screen to achieve a proper balance.
2. With the room dark and the lights turned on, hold up your hand between the lights and the screen. Three shadows will be produced and colored yellow, cyan, and magenta.
3. Move your hand closer to and then farther away from the screen. The shadows will get closer together and overlap and then move farther away from each other.

DISCUSSION:

NASA's Hubble Space Telescope is able to gather light information of objects in space and transmit it to Earth in digital form to enable computers to create colored images. However, colored images are not transmitted to Earth. Only images in shades of gray are transmitted. To produce colored images, the objects the telescope is directed at are examined through colored filters that blot out various wavelengths of light. Each filter used yields a separate image of the object in a particular wavelength of light.

Classroom Activities



Water Prism

Subject: Visible light spectrum
Topic: Constructing a water prism
Description: Materials and procedures for constructing a water prism out of glass and silicone cement and using it to break down white light into rainbow colors.
Contributed By: Gregory Vogt, JSC

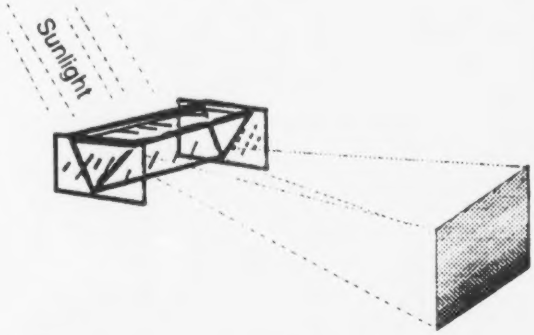
Materials:

3 pieces of window glass 6 inches by 12 inches*
2 pieces of window glass 6 inches by 8 inches
Silicone cement (clear)
Emery paper
Cellophane tape
Water

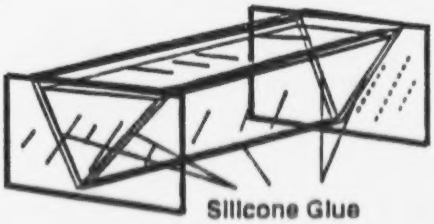
*Purchase all the above items (except water) from a hardware store. The store will cut the glass to size.

Procedure:

1. Before assembling the water prism, make sure the pieces of glass are free from sharp edges. Smooth out any sharp parts with the emery paper. Wash the glass clean of any grease and dirt and dry completely before following the next steps.
2. Arrange the two larger pieces of glass (sides) to form a V-shaped trough. Temporarily hold the trough together by taping it on the outside.



3. Stand the trough up on one of the end pieces.
4. Squeeze some silicone cement along the inside edges of the trough where they touch the end piece. Make sure the cement fills the seam. Let the cement dry before moving on to the next step.
5. Carefully invert the trough and place it on the other end piece as before. Cement the trough to the end and let it dry.
6. Stand the trough upright and cement the inside seam to completely seal the trough.
7. When the cement is dry, lay the trough on a kitchen counter and test it for leaks. Pour water into the trough until it is nearly full. If there are any leaks, empty



the trough and let the inside dry. Add more cement to the area that leaked and repeat the test when the cement dries.

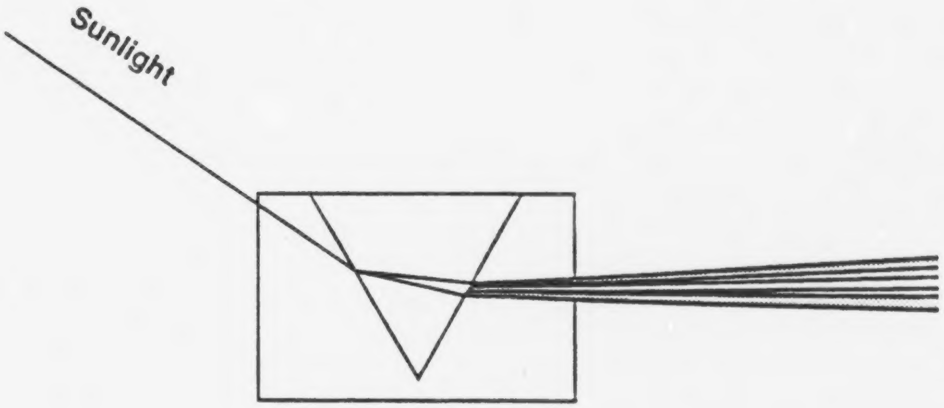
8. Place the finished water prism in a sunny window and fill nearly to the top with water. Place the remaining piece of glass over the top to serve as a cover. When the Sun reaches the right angle, white light will spread out into rainbow colors and fall on the wall across the room. Look through the prism to the outside and see rainbow colors as well.

Discussion:

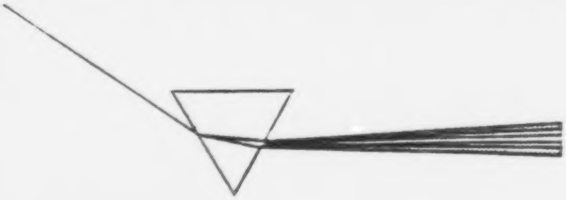
The water prism substitutes water for a solid glass or clear plastic prism. Sunlight enters the prism from one of its sides. As the light enters the glass and water, it is bent slightly upward. The light bends again as it leaves the other side. Violet light bends more than blue light, which bends more than green, etc. In this manner, all the colors that make up the visible spectrum (red, orange, yellow, green, blue, indigo, and violet) are spread out from each other so that they can be identified.

Check a standard physical science or physics textbook or an encyclopedia for an explanation of why the "rainbow" colors spread out as white light passes through a prism.

Spectroscopes, devices that measure the components of light, are used by astronomers to identify the composition of distant stellar objects. Every element gives off its own distinctive light when heated. The light produced is like a finger print that enable astronomers to identify it. Using a spectroscope, an astronomer can break down the light from a distant star to identify the specific elements that make up that star.



Classroom Activities



Projecting Rainbow Colors

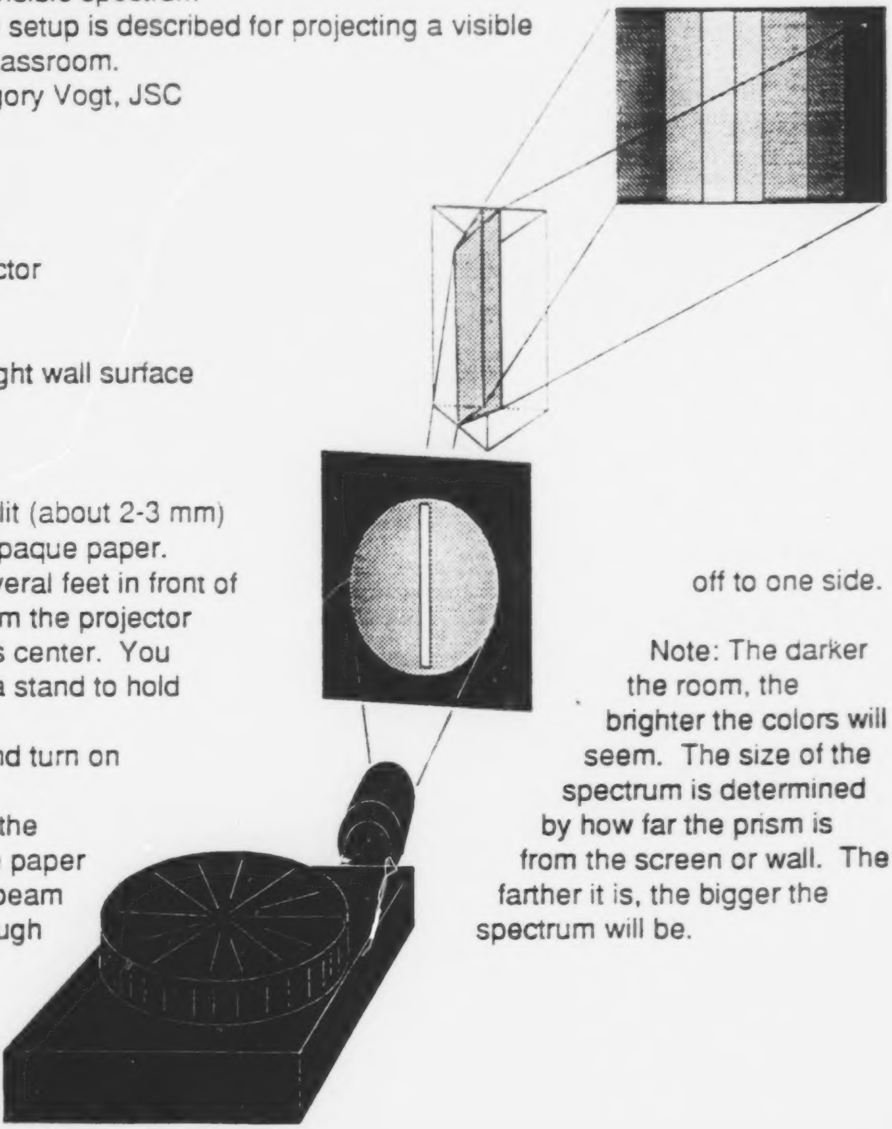
Subject: Visible light spectrum
Topic: Projecting the visible spectrum
Description: A simple setup is described for projecting a visible light spectrum in the classroom.
Contributed By: Gregory Vogt, JSC

Materials:

Glass or plastic prism
Slide or filmstrip projector
Opaque cardboard
Razor blade knife
Projection screen or light wall surface

Procedures:

1. Cut a very narrow slit (about 2-3 mm) wide in a piece of opaque paper.
2. Place the paper several feet in front of the projector and aim the projector beam at the paper's center. You may wish to make a stand to hold the paper.
3. Darken the room and turn on the projector.
4. Place the prism on the opposite side of the paper so that the narrow beam of light passes through it.
5. Rotate the prism until a spectrum is produced. The spectrum will be off to one side.



Note: The darker the room, the brighter the colors will seem. The size of the spectrum is determined by how far the prism is from the screen or wall. The farther it is, the bigger the spectrum will be.

Description:

The projector light enters the prism from one of its sides. As the light enters the glass or plastic prism, the light is bent slightly one the side. The light bends again as it leaves the prism. Violet light bends more than blue light, which bends more than green, etc. In this manner, all the colors that make up the visible spectrum (red, orange, yellow, green, blue, indigo, and violet) are spread out from each other so that they can be identified.

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Classroom Activities

Make A Spectroscope

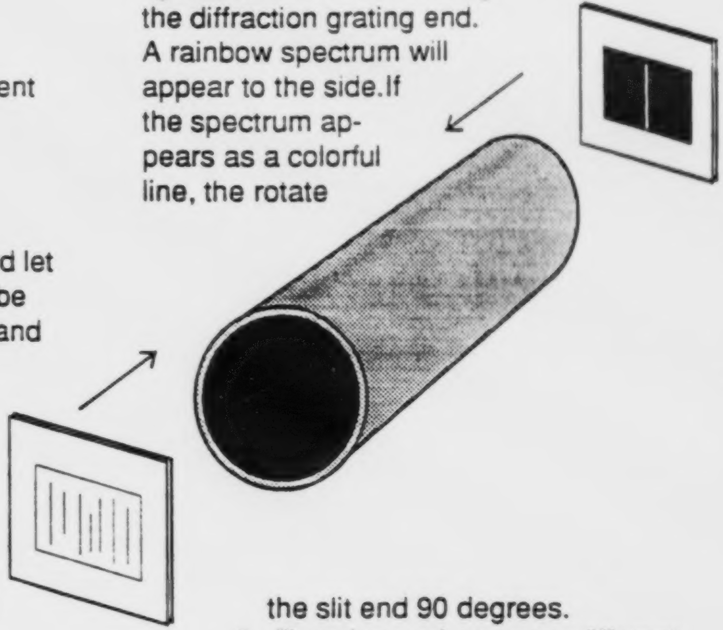
Subject: Visible light spectrum
Topic: Making a spectroscope
Description: A simple spectroscope is made from diffraction grating and paper.
Contributed By: Gregory Vogt, JSC

Materials:

Diffraction grating
Cardboard 35 mm slide mount (2)
Black paper
Paper tube (about 15 cm long)
Black paint
Scissors
Razor blade knife
Rubber cement
Various light sources (sunlight, florescent light, incandescent light, etc.)

Procedures:

1. Paint the inside of the tube black and let dry. (Black construction paper can be substituted for the paint and rolled and placed inside the tube.)
2. Cut a small rectangle of diffraction grating and mount it in a 35 mm slide frame. Seal the frame with a hot iron. Be careful not to touch the diffraction grating. Before cutting the grating, examine it and look for tiny lines. The lines should run up and down with relation to the frame. See diagram.
3. Apply rubber cement to the one end of the tube and to the slide frame. Allow to dry. Repeat. When dry, press the frame to the end.
4. Mount a small rectangle of black paper in the second slide frame and seal.
5. Cut a very narrow vertical slit in the paper as shown in the diagram.
6. Cement the second slide frame to the other end of the tube. The slit should be parallel to the tiny lines in the diffraction grating.
7. Aim the slit end of the spectroscope at a lightsource and look through the diffraction grating end. A rainbow spectrum will appear to the side.If the spectrum appears as a colorful line, the rotate the slit end 90 degrees.



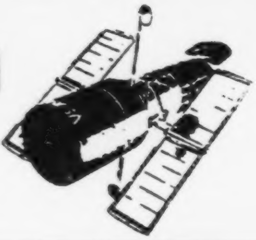
8. Examine and compare different light sources with the spectroscope.

Discussion:

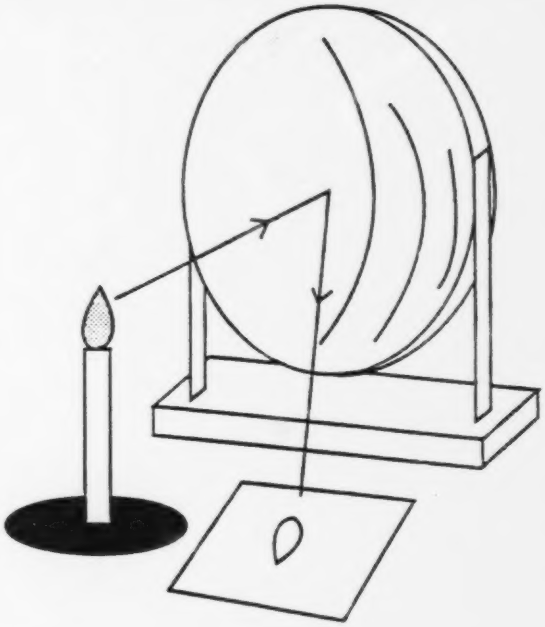
Like a prism, diffraction gratings break up light into its component colors. The surface of the grating is filled with thousands of tiny scratches. The scratches, if magnified and seen from the side, look like the peaked rooftops of closely spaced houses (like a thousands of prisms placed side to side). Light bends through the scratches as it does through large prisms. The slit, reduces the amount of light entering the spectroscope so that the spectrum is much easier to see.

Research quality spectroscopes add a measurement scale so that the specific wavelengths of light can be measured. This leads to the identification of the elements and compounds that produced that light. This is possible because every element gives off its own distinctive light when heated. The light produced is like a finger print that enable astronomers to identify it. Using a spectroscope, an astronomer can break down the light from a distant star to identify the specific elements that make up that star.

Classroom Activities



Reflecting Telescope Demonstration



SUBJECT: Astronomy
TOPIC: Telescopes
DESCRIPTION: A concave makeup mirror is used to demonstrate the principle behind the design of a reflector telescope.
CONTRIBUTED BY: Gregory Vogt, OSU

MATERIALS:

- Concave makeup mirror
- Candle
- Matches
- Dark room
- Sheet of white paper

PROCEDURES:

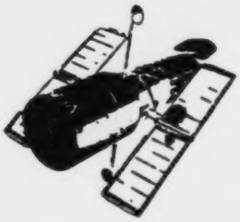
1. Darken the room and light the candle.
2. Bring the concave makeup mirror near the candle flame and tilt and turn it so that reflected light from the candle flame focuses on a sheet of white paper.

DISCUSSION:

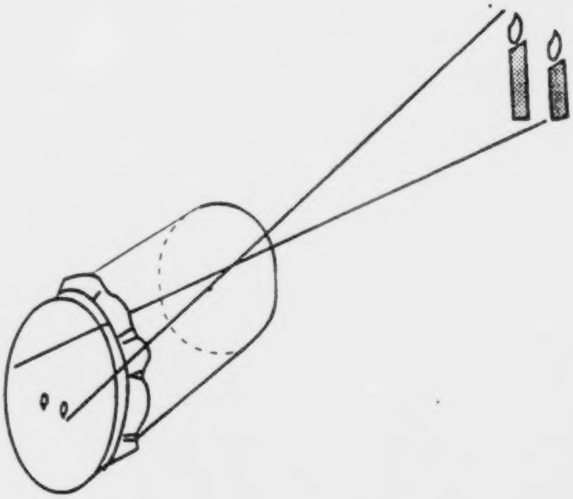
Many reflector telescopes gather light from distant objects with large parabolic mirrors that direct the light toward secondary mirrors and then towards eyepieces for viewing. The concave mirror used in this demonstration shows how a curved mirror can concentrate light to project and form a recognizable image. The image produced with a makeup mirror is not well focussed because the mirror is inexpensively produced from bent glass rather than being made from heavy glass that is carefully ground and shaped into a proper curve.

With larger astronomical telescopes, eyepieces are not used. The collected light is aimed at photographic film or at electronic light detectors that produce images through computer processing. This demonstration shows how an image is formed on a flat surface. If the paper were replaced with photographic film, a crude picture could be produced.

Classroom Activities



Pinhole Viewer



SUBJECT: Astronomy
TOPIC: Telescope optics
DESCRIPTION: The inversion images produced by convex lenses is demonstrated with a pinhole viewer.
CONTRIBUTED BY: James McMurtry, SSC

MATERIALS:

- Circular cereal box
- Tracing paper
- Rubber band
- Candle
- Sharp nail or compass point
- Double convex lens (magnifying glass)
- Dark room

PROCEDURES:

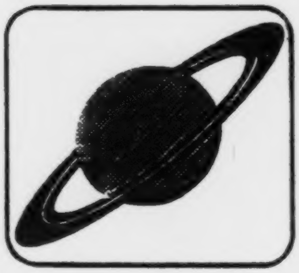
1. Punch a small hole in the bottom of the cereal box at its center.
2. Cover the open end of the box with tracing paper and hold in place.
3. Light the candle and darken the room.
4. Aim the pinhole viewer so that the pinhole is pointed at the candle. Observe the image on the tracing paper.
5. Compare the image produced by the pinhole viewer with the image seen through a double convex lens.

DISCUSSION:

Convex lenses invert images. Light rays converge behind these lenses and cross at the focal point. At that point, the image becomes inverted. With the pinhole viewer, the inversion takes place at the pinhole.

Astronomical telescopes produce images that are inverted. Images can be corrected but it would be necessary to add additional lenses or prisms to do so. Additional lenses or prisms filter out some of the light, making the image seen darker than would be seen without them. Astronomer's prefer brighter images and since most observing work is done with photographic film, images can be corrected simply by turning around and flipping the photographic negative upside down.

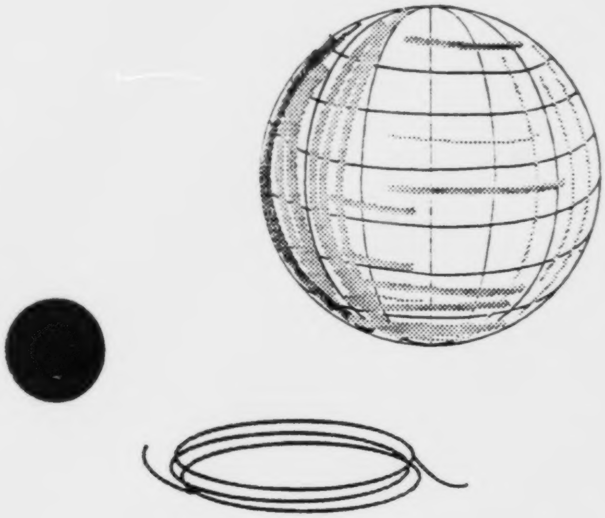
Classroom Activities



Earth-Moon Distance

SUBJECT: Astronomy
TOPIC: Distance to the Moon
DESCRIPTION: A simple scale model is created for visualizing the distance between the Earth and the Moon.

MATERIALS:
World globe (12 inches in diameter)
Tennis ball
String or twine (about 20 feet long)



PROCEDURE:

1. With the tennis ball representing the Moon, ask students to place the tennis ball at a distance from the globe that represents how far the Moon is from the Earth.
2. Ask students to determine the circumference of the Earth and the distance between the Earth and the Moon by consulting a reference book. (Note: the Earth's circumference is about 25,000 miles and the distance between the Earth and the Moon is about 240,000 miles.)
3. Ask the students to divide the distance to the Moon by the circumference. (The answer is 9.6. Round it off to 9.5.)
4. Compare the earlier estimate of the distance between the Earth and the Moon with a measured distance based on the Earth's circumference. Wrap the string around the globe 9.5 times. Hold one end of the string at the surface of the Earth and stretch the measured string across the classroom. The other end of the string represents the distance of the Earth to the Moon.

DISCUSSION:
This activity provides a visual demonstration of the distance between the Earth and the Moon. Relative positions of bodies in space is difficult to visualize because of the enormity of the distances between them. Scale models provide an opportunity to put meaning to astronomical numbers. For a follow-up activity, create a larger model of the Moon and the Earth with chalk on a play ground. The diameter of the Moon should be 1/4th of the diameter you choose for the Earth.

Measuring The Sun

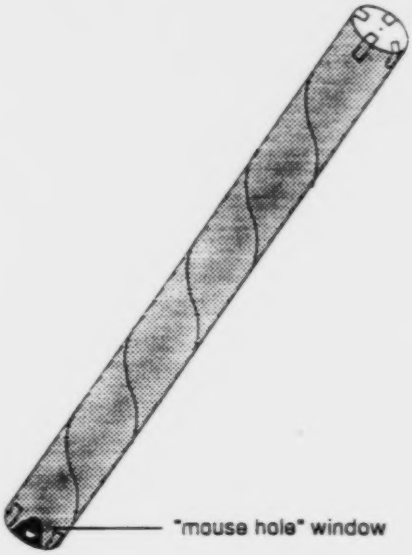
SUBJECT: Astronomy
TOPIC: Sun's diameter
CONTRIBUTED BY: Gregory Vogt, OSU
DESCRIPTION: A simple viewing device is constructed for estimating the Sun's diameter using similar triangles.

MATERIALS:

Package wrapping paper center tube or heavy paper rolled and taped to form a tube.
1 3X5 file card
Sewing pin
Graph paper (10 squares to the centimeter)
Cellophane or masking tape
Scissors
Metric ruler
Pencil

PROCEDURE:

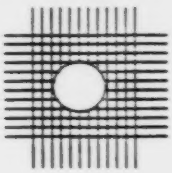
1. Cut the tube so that it is 0.5 meters long. Do this step as carefully as possible.
2. Cut out a small "mouse hole" window in one end of the tube as shown in the picture.
3. Trace the end of the tube with the pencil on the file card and on the graph paper. Cut out both circles.
4. Tape the file card paper circle to the end of the tube opposite the window. Tape the graph paper circle with the graph lines inward to the other end. Make sure the circles are taped flat across the ends. If the circles are bent outward or inward, they will change the length of the tube.



5. Use the sewing pin to punch a small hole through the center of the file card circle. The solar viewer is complete.

MEASURING THE SUN:

Take the solar viewer outside on a sunny day. Point the file card end of the viewer towards the Sun while you are looking through the window at the graph paper. It may take some practice in pointing the viewer in the correct direction. **Do not sight the viewer like a rifle because you can injure your eyes!** When the viewer is properly aimed, a small circular image of the



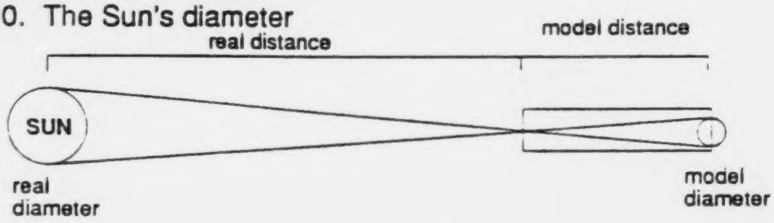
Sun will appear on the graph paper. Use the lines of the graph paper to measure the Sun's diameter in millimeters.

CALCULATION:

The Sun's actual diameter can now be estimated with simple geometry. The tube you created is a scale model of the distance of the Earth to the Sun. Sunlight enters the pinhole and is focused on the graph paper. In the model, the pinhole represents the position of the Earth and the graph paper the position of the Sun. We know how far apart the two positions are on our model— 0.5 m or 500 millimeters. With careful range finding measurements by professional astronomers, we also know the real distance to the Sun— 150,000,000 kilometers. In other words, 500 mm on the model equals 150,000,000 km in real life. With division, we find that the scale of our model is 1 mm = 300,000 km in real life. You measured the model diameter of the Sun and found that it was (for discussion) 10 millimeters, you could now estimate the Sun's real diameter—10 X 300,000. The Sun's diameter would be 3,000,000 km. All you have to do is multiply the number of millimeters you measured for the Sun's image by 300,000 km and you will have the actual diameter.

DISCUSSION:

This activity works best if several people each measure the Sun and each calculate its diameter. The method is imprecise but a greater accuracy can be achieved by averaging each answer together. Small measuring errors usually cancel out. The actual diameter of the Sun is approximately 1,390,000 km. This works out to a model diameter of 4.63 mm. The graph paper is not precise enough to measure this diameter precisely but student measurement usually range from 4 to 5 mm and averaging will approach the actual diameter of the image.



Classroom Activities

Martian Canals

SUBJECT: Astronomy
TOPIC: Remote Sensing
DESCRIPTION: A possible resolution of the "true" origin of the Martian canals is demonstrated with a pencil and paper activity.

CONTRIBUTED BY: Gregory Vogt, OSU

MATERIALS:

Enlarged version of the figure
Blank drawing paper
Marker pens or dark crayons

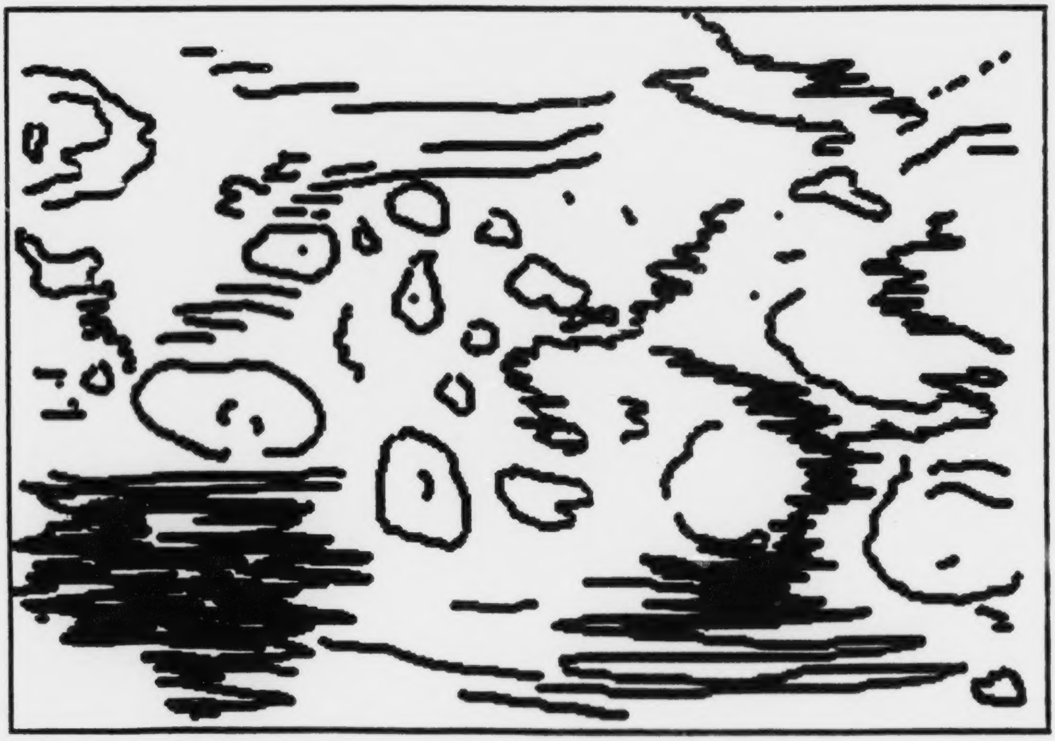
METHOD:

1. Draw an enlarged version (about 21 x 28 cm) of the figure on a piece of white paper.

2. Distribute blank paper and markers or crayons to the class. Hold the figure up in front of a class for two minutes.

3. Instruct the class to quickly copy the figure on their paper.

4. After two minutes, collect the drawings from the students. As they are collected, mark each one with a code indicating how far the student who drew each picture was away from the original.

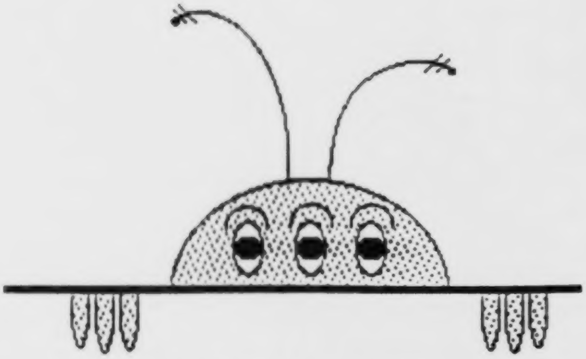


5. Affix each drawing to a bulletin board and arrange them by distance.

6. Compare the drawings to each other. What differences are visible between the close up and far student drawings?

DISCUSSION:

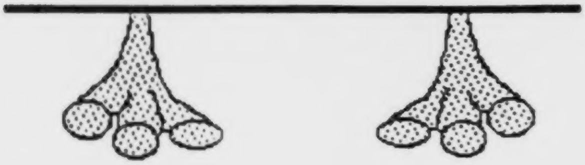
In 1878, Giovanni Virginio Schiaparelli, directory of the Brera Observatory in Milan, Italy, published "Astronomical and Physical Observations on the Axis and Rotation and on the Topography of the Planet Mars." The report was probably the first official mention to the scientific community of his discovery of *canali* crossing the surface of Mars. The word means "channels" but it was promptly mistranslated by news reports as "canals." On Earth, canals were made by humans. Schiaparelli's report triggered a Martian odyssey lasting close to 100 years. The popular press and notable scientists took the discovery to mean that the planet was populated by "intelligent creatures, alike to us in spirit, though not in form." Other scientists believed Schiaparelli was just connecting, in his mind, the shadowy features on the Martian surface into an elaborate network of canals. Eventually, the Italian astronomer believed he had identified 113 canals. The American astronomer Percival Lowell elaborated on the observations and boosted the canal count to 500 and further identified 200 "oases." A scientific debate ensued that was not finally laid to rest until 1972 when Mariner 9 orbited the Martian surface and sent back thousands of pictures, none of which showed any canals.



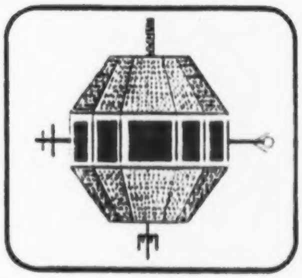
In 1913, E.W. Maunder, conducted an experiment with 200 English schoolboys in which he hoped to show the Martian canals were just optical illusions. He instructed the schoolboys to copy a figure like the one on this page. Maunder found that the farther away the drawer of the picture was from the original, the less detail and the straighter the lines on the copy became. His experiment provided a strong indication that the Martian canals were merely chance alignments of surface features and colorings on Mars that appeared to be linear.

Incidentally, Mariner 9 did detect hundreds of real channels on Mars but none were large enough to be seen from Earth.

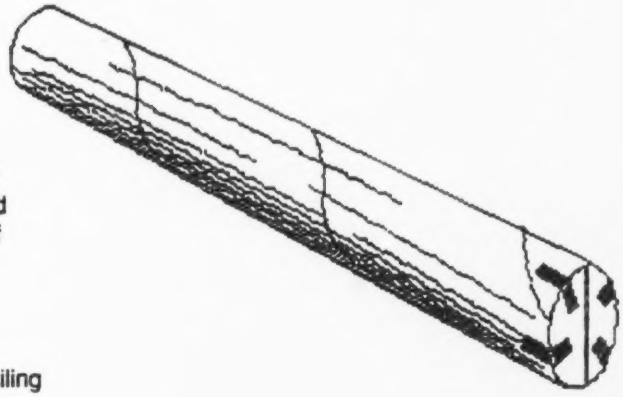
REFERENCES: Vogt, G. L., (1978) "Lessons from the Great 'Canal' Dispute," *The Science Teacher*, v45n7, pp27-29.



Classroom Activities



Pictures From Space



SUBJECT: Astronomy, Remote Sensing
TOPIC: Image scanning and reconstruction
DESCRIPTION: The process by which optical scanning devices collect images and how they are reassembled is graphically demonstrated by the use of the eye's property of persistence of vision.
CONTRIBUTED BY: Gregory Vogt, OSU

MATERIALS and TOOLS:
Long paper tube (from roll of wrapping paper, mailing tube, or taped roll of construction paper)
File card
Scissors
Cellophane or masking tape
Pencil
Straight edge

METHOD:

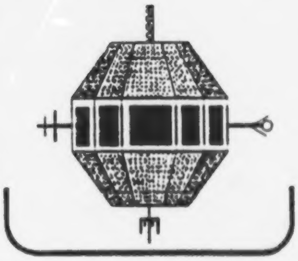
1. Trace the end of the tube on a file card to form a circle slightly larger in diameter than the diameter of the tube.
2. Draw a straight line through the middle of the circle. Cut out the circle from the card and then cut it in half along the line.
3. Tape the two halves of the circle to one end of the tube but leave a narrow gap or slot between them approximately 1 to 2 mm wide.
4. Hold the open end of the tube to one eye while the other eye is closed. Slowly pan the tube around the room. Try to identify what you see through the narrow slit.
5. Again holding the tube, pan the tube around the room but this time move it rapidly. Try to identify what you see through the narrow slit.

DISCUSSION:

Many images of the Earth and planets are transmitted to Earth from spacecraft as long strings of data. The data is generated by scanning devices within the spacecraft imaging system that rapidly measure reflected light from their subjects one line at a time. Light values are converted into radio signals. Waiting computers on Earth process the signals back into individual lines that are organized into images in a high tech version of a paint-by-number picture.

Individual lines in a picture are virtually unrecognizable. It is when they are assembled to form a complete image that they take on meaning. The same thing takes place with the paper tube. When the tub is panned slowly, momentary lines of light received in the eye mean very little to the viewer. However, when the tube is rapidly panned, the lines combine together to form a recognizable image. This takes place because of the eye's property of persistence of vision. The eye momentarily retains images which provide ample time for many scan lines to combine.

Classroom Activities



Orbital Forces

SUBJECT: Space Science
TOPIC: Orbits
DESCRIPTION: A ribbon is attached to a tennis ball and swung in a circle to demonstrate orbital motions and forces.
CONTRIBUTED BY: Dale Bremmer, HQ and Norman O. Poff, OSU

MATERIALS AND TOOLS:

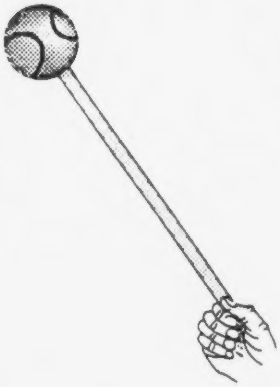
Tennis ball
1 Yard of 1 inch wide cloth ribbon
1 Dowel rod 2 inches long by 3/16" diameter
Needle and thread
Sharp knife
White glue

PROCEDURE:

1. Loop one end of the ribbon over the dowel rod and glue the rod and tape together. For added strength, stitch the overlapping ribbon pieces together before the glue dries.
2. Hem the other end of the ribbon to prevent raveling.
3. Cut a 1 inch wide slit in the tennis ball.
4. Slip the dowel and ribbon at an angle through the slit in the tennis ball. The dowel rod will prevent the ribbon from being pulled out.

DEMONSTRATION:

Hold the free end of the ribbon and swing the ball in a circle. Feel the forces at work. Let go of the ball and watch which direction it travels. The ribbon makes it easier to follow the direction of the ball.



DISCUSSION:

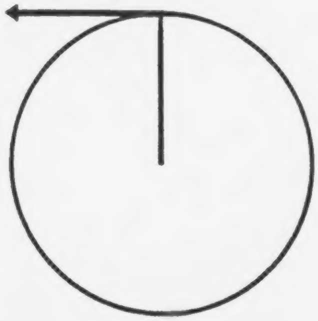
Students and adults alike are often confused about the forces and motions at work when a satellite orbits the Earth. People, who seem to know what is happening, will say that "...the centrifugal force or outward pulling force of the satellite's motion is exactly balanced by the inward pull of the Earth's gravity." The explanation sounds good but it is not backed by actual observation.

The tennis ball and ribbon demonstration is a good analogy of a satellite in orbit. The pull of your hand through the ribbon represents gravity. The outward pull of the moving tennis ball represents centrifugal force—

or does it? When you released the tennis ball so that it could fly away, which direction did it travel? Did it travel straight outward from your hand on a path in line with the ribbon at the moment of its release? Actually, the ball traveled in a straight path but at a right angle to the ribbon at the moment of release. In other words, the ball followed a tangential path to the circle it was originally traveling in. This is an important observation and it shows that the outward-pulling force is not what you are feeling at all. "Centrifugal force" is a convenient way of describing what is happening but it is actually a myth. It doesn't exist! If it did exist, the ball would have flown straight out—which it didn't.

What is actually taking place can best be explained by resorting to Isaac Newton's first law of Motion. Part of this law states that an object in motion will move in a straight line unless acted on by an unbalance force. In the case of a satellite in space, the launch vehicle that carried it up to orbit aimed it in a direction parallel to the Earth's surface. According to Newton's first law, the satellite will travel in a straight line. This doesn't happen because gravity pulls on the satellite and bends its path in a circle. Gravity is an unbalanced force.

While it is not possible to shut off gravity to see what would happen to the satellite's motion, it is possible to release the end of the ribbon holding the tennis ball. As the ball swings around you, the outward pull you feel on the ribbon is actually the ball trying to travel in a straight line. Your inward pull is the unbalanced force that keeps the ball traveling in a circle. When you release the ball, the ball travels away in a straight line in the exact direction it was traveling at the moment you released it.



When released, the ball will fly off on a tangent to the circle.

Classroom Activities

Gravity Well

TOPIC: Orbits
DESCRIPTION: A gravity well is used to investigate the orbits of planets, moons, and artificial satellites.
CONTRIBUTED BY: Gregory Vogt, HQ/JSC

MATERIALS NEEDED:
3-ply trash bag
Large wooden, metal, or plastic bowl
Masking tape
Heavy string
Large bead
Rubber cement
Drill and small bit
Small marbles or ball bearings
Paper
Scissors

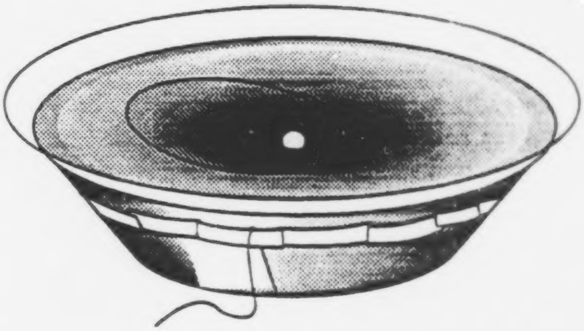
PROCEDURE:

Step 1. Drill a small hole in the bottom of the bowl

Step 2. Tie a knot in one end of the string and slip the bead over the other end.

Step 3. Cut a circle from the plastic bag that is a few centimeters greater in diameter than the bowl.

Step 4. Poke a small hole in the center of the plastic circle. Slip the end of the string through the hole.



Step 5. Slip the string through the hole in the bowl from the top. Tape the plastic over the rim of the bowl so that it is drum head tight.

Step 6. Coat the plastic around the hole with rubber cement. Also coat the bottom side of the bead with rubber cement. Let the cement dry. Pull the string until the cemented surface of the bead and the cement on the plastic come into contact.

Step 7. Pull the string tight to stretch the plastic to form a funnel shape in the center of the plastic. Tape the string to the side of the bowl to hold it tight.

Step 8. (Optional) To help keep the marbles from running off the edge, you may wish to tape a paper rim around the lip of the bowl.

USING THE GRAVITY WELL:

Roll a marble around the well. The shape of the well will cause it to orbit the center. Try to make circular orbits. Observe the path the marble takes and how its speed changes.

DISCUSSION:

The curvature of the gravity well simulates the gravitational field of the Sun or any other body in space. According to Isaac Newton's Universal Law of Gravitation, the force of gravity (pull that is felt) between two bodies is directly proportional to the mass of those bodies and inversely proportional to the square of the distances between their centers. In other words, the more massive the two bodies are, the greater the pull and the farther they are apart from each other the lesser the pull. Because of the inverse square relationship in the law, the pull two bodies have on each other varies dramatically with distance. If the distance between the two bodies is doubled, their mutual pull is reduced to only one quarter as much. If the distance is tripled, the pull is only one ninth as much.

The change in gravitational pull with distance is simulated with the gravity well by the shape the plastic is stretched into. The curve in the plastic is gentle near the edges but very steep in the middle. As the marble orbits near the rim, it rolls more slowly then when it rolls toward the middle. As it rolls to the middle, it picks up speed as though it were being pulled upon more strongly. By stretching the plastic more or less (pulling on the string), it is possible to vary the gravitational pull of the central body.

In practice, it is much easier to achieve an elliptical orbit than a circular orbit in the gravity well. Even when the orbit is very circular, it is still slightly elliptical in shape. The same holds true with the way planets, moons, and artificial satellites orbit in space.

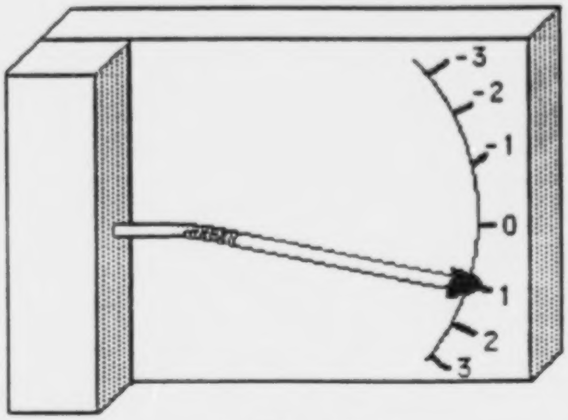
The gravity well demonstrates all three of Johannes Kepler's laws of planetary motion. The first law states that the orbit of a planet is an ellipse with the Sun is positioned at one focus. (Unlike circles, ellipses have two foci.) The bead in the gravity well represents the Sun. The second law points out, in effect, that orbiting bodies move faster when they are near the Sun and slower when farther away. Speed changes of the marble can easily be observed in the gravity well. The third law, relates states that the orbital period of a planet is proportional to the square of its average distance from the Sun. In other words, the farther a planet is from the Sun, the longer it takes to complete one orbit.

Gravity wells can be made much larger. A trash can make a suitable container. Because of its extra diameter, two or more beads can be can be used to simulate the gravitational fields of a multiple star system.

Classroom Activities

Gravity Meter

SUBJECT: Manned Space Flight
TOPIC: Gravity forces produced by acceleration and deceleration during rocket launch, orbital velocity changes, and reentry.
DESCRIPTION: A simple meter is constructed that can be used to make approximate measurements of G-forces.
CONTRIBUTED BY: Gregory Vogt, OSU



Vertical Mode

1 board 12"x15"x1"
1 board 12"x2"x1"
1 3/16" or 1/4" dowel rod
1 compression spring (the spring should fit snugly over the end of the dowel rod and not be very stiff.)
3 fishing sinkers (about 1/2 ounce each. Worm sinkers have a pointed shape on one end and make good pointers.)
Drill and bit
Wood glue and screws or clamps

PROCEDURE:

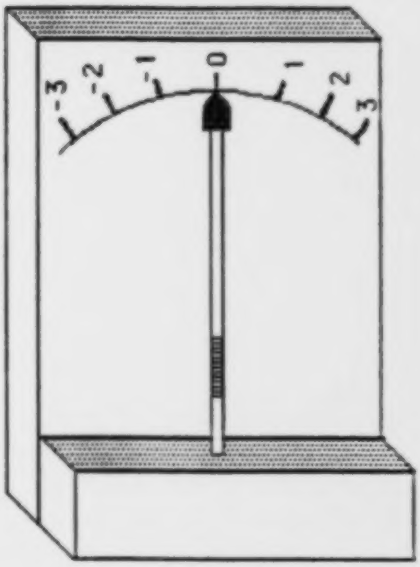
1. Drill a hole in the middle of the edge of the smaller of the two boards. The hole should be just large enough to insert a short (about 1 1/2 to 2 inch) piece of dowel rod into it.
2. Glue and screw or clamp (until the glue is dry) the small piece of wood into the other board as shown.
3. Slide one end of the compression spring onto the dowel piece.
4. Cut 3 pieces of dowel rod 9 inches long.
5. Carefully drill short holes into the 3 fishing sinkers. Hold the sinkers in a vice when you drill them. Insert one dowel rod into each sinker hole. If the sinkers are a bit loose, hold them in place with a small amount of tape.
6. Stick the other end of one of the three dowel rods into the open end of the compression spring.
7. Set the G-meter on a table so that the dowel rod is horizontal and mark the position of the center of the sinker. This equals a 1-G environment. Temporarily attach one of the other pointers to the first and mark the 2-G position. Then do the same with the third pointer and mark the 3-G position. Remove the two extra pointers. Next, set the G-meter upside down and again mark the 1, 2, and 3-G positions. Add minus signs to these marks for negative Gs. The G-meter is ready to use.

MEASURING G FORCE

In addition to using this G-meter on a roller coaster or on an elevator (see companion activity - "Vertical G-Meter") the horizontal/ vertical G-meter can be used to measure the G forces in a car as it accelerates away from an intersection or makes a fast stop. Hold the G-meter on its side. You will probably have to brace it against the side window to get the best measurements. When the car is at rest, the pointer will point straight up for 0-G. The pointer will swing back as the car accelerates forward and it will swing forward when the car slows down. In the vertical mode, this G-meter is held on its side and the pointer points to the 1-G position. If the meter goes up suddenly, the pointer will swing down. If the G-meter goes down suddenly, such as the holder steps off a high diving board, the pointer will swing up to the negative G range.

DISCUSSION

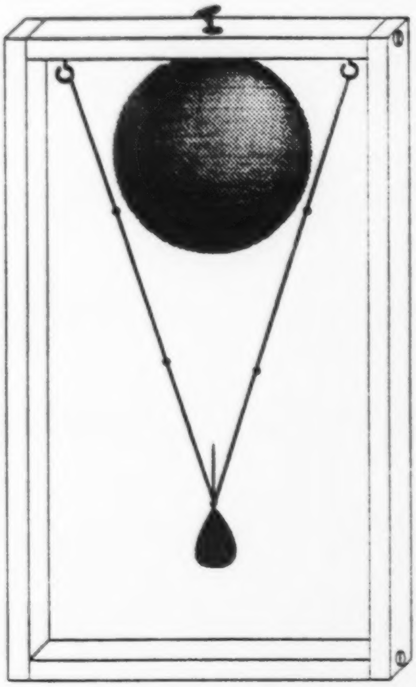
(Refer to the companion activity *Vertical G-Meter.*)



Horizontal Mode

WEIGHTLESS DEMONSTRATOR

SUBJECT: Space Science
TOPIC: Weightlessness
DESCRIPTION: A balloon is punctured with a pin, showing that a lead weight becomes weightless during free fall.
CONTRIBUTED BY: Gregory Vogt, OSU



MATERIALS AND TOOLS:
2 Pieces of wood 16"X2"X1"
2 Pieces of wood 10"X2"X1"
4 Wood screws (#8 or #10 by 2")
Glue
2 Screw eyes
6 Rubber bands
1 3 oz fishing sinker or 3 1 oz fishing sinkers (taped together)
Long sewing pin or needle
Small round party balloons
Drill, 5/8" bit, and bit for piloting holes for wood screws
Screw driver
Pillow or chair cushion

PROCEDURE:

1. Assemble the supporting frame as shown in the diagram. Be sure to drill pilot holes for the screws and glue the frame pieces before screwing them together.
2. Drill a 5/8" inch-diameter hole through the center of the top of the frame. Be sure the hole is free of splinters.
3. Screw the two screw eyes into the underside of the top cross member of the frame as shown in the diagram. (Before doing so, check to see if the metal gap at the eye is wide enough to slip a rubber band over it.) If not, use pliers to spread the gap slightly. (see figure)
4. Loop three rubber bands together and then loop one end through the metal loop of the fishing sinker(s).
5. Follow the same procedure with the other three rubber bands. The fishing weight should hang downward like a swing near the bottom cross member of the frame. If the weight hangs near the top cross member, the rubber bands are too strong.

Replace them with thinner rubber bands.

6. Attach the pin or needle, with the point upward, to the metal loop of the fishing weight. It may be possible to slip it through the rubber band loops to hold it in place. If not, use a small amount of tape to hold it in place.
7. Slip a round party balloon through the hole in the upper cross member of the frame so that the nozzle is pointed up. Inflate the balloon and tie off the nozzle.
8. Place a pillow or cushion on the floor. Raise the demonstrator at least 6 feet off the floor. Do not permit the weight to swing. Drop the entire unit on to the cushion. The balloon will pop almost immediately.

DISCUSSION:

Earth orbiting spacecraft experience a condition described as weightlessness. The spacecraft is in a state of free-fall as it orbits. If the spacecraft has astronauts on board, the astronauts are able to move about with ease because they are in free-fall too. In otherwords, everything in their immediate world is falling together. This creates the weightless condition. Crew members and all the other contents of the spacecraft seemingly float through the air.

On Earth, momentary weightlessness can be created in a number of ways. Some amusement parks achieve a second or two of weightlessness in certain wild "high-tech" rides. A springboard diver feels a moment of weightlessness at the top of a spring just as the upward motion stops and just before the downward tumbling motion to the water below begins. As the diver falls, friction with air quickly robs the weightless sensation and produces drag that returns at least a portion of the diver's weight before striking the water. NASA eliminates the air friction problem and achieves about 30 seconds of weightlessness with a special airplane than carries astronauts on training flights. The plane begins a long arcing dive towards the Earth at a speed equal to the acceleration of a falling object. After 30 seconds, the plane pulls out of the dive and climbs back to high altitude to begin another weightless cycle. The airplane's skin and engine thrust during the dive totally negate the effects of air friction.

The weightless demonstrator is an ideal device for demonstrating weightlessness in the classroom. When stationary, the lead fishing weight stretches the rubber band so that the weight hangs near the bottom. When dropped, the entire device experiences a moment of weightlessness. The rubber bands are still stretched and they immediately yank the now weightless lead weights and the top of the frame together. The balloon gets in the way and is popped by the pin.

The demonstration works best when students are asked to predict what will happen when the frame is dropped. Will the balloon pop and if so, when will it pop during the fall? If your school has video tape equipment, you may wish to videotape the demonstration and then use the slow controls on the playback machine to determine more precisely when the balloon popped.

Classroom Activities

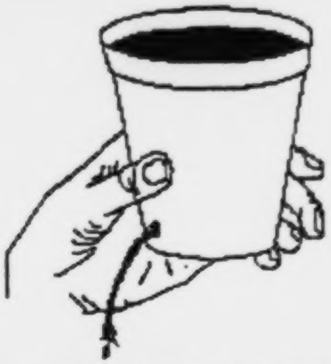
Zero-G Demonstrator

SUBJECT: Space Flight
TOPIC: Free fall
DESCRIPTION: A water stream coming out of a hole in a styrofoam cup stops when the cup is dropped.
CONTRIBUTED BY: Dale Bremmer, HQ

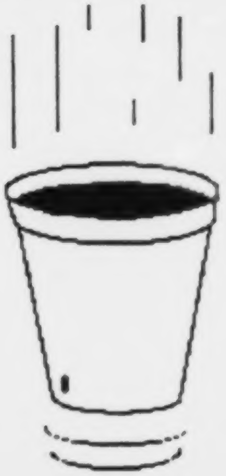
MATERIALS:
Styrofoam coffee cup
Pencil or other pointed object
Water
Bucket or other water catch basin

PROCEDURE:
1. Punch a small hole in the side of a styro foam cup near its bottom.
2. Hold your thumb over the hole as you fill the cup with water. Ask students what will happen if you remove your thumb.
3. Remove your thumb and let the water stream out into the catch basin on the floor.
4. Again seal the hole with your thumb and refill the cup. Ask students if the water will fall out of the hole if you drop the cup as you remove your thumb.
5. Drop the filled cup into the catch basin. The demonstration is more effective if you hold the cup high before dropping it.

DISCUSSION:
Zero-G that astronauts experience inside the Space Shuttle is really not zero-G at all. Zero-G implies that gravitational pull in space is zero. This is not the case. Astronauts "float" in space because they are in a state of free fall produced by their orbital motions around the Earth. Astronauts and their spacecraft are falling together. The condition is better described as "weightlessness" because a bathroom scale inside the Shuttle would not record any weight for an astronaut standing on it. The scale would be falling too.



The falling styrofoam cup demonstrates weightlessness (or zero-G) for a brief period of time. When stationary, water freely pours out of the cup. If the cup falls too, the water remains inside the cup for the entire fall. Even though the water remains inside, it is still attracted to the Earth by gravity and it ends up in the same place that the water from the first experiment did.



Classroom Activities

The Astronaut Game

Subject: Communications
Topic: Human space spaceflight
Description: The need for accurate communications in manned spaceflight is demonstrated with a simple game involving paper and pencil.
Contributed By: Dr. Harry B. Herzer, III, HQ (adapted from an activity by the same name)

Materials:

Pencil or marker pen and a clean sheet of paper for each team of 4 students
Copy of the artwork on the next page for each team

Procedure:

1. Divide students into teams of 4 or 5.

2. Instruct each team to assign team members to the following jobs:

   Astronaut
   Communication Satellite
   Tracking Station
   Data Relay System (if team has five members)
   Mission Control

3. Explain to each team that a manned landing on the Planet Mars has taken place. Unfortunately, a malfunction in the landing craft's television transmission system has developed preventing scientists on Earth from seeing pictures of the Martian terrain. The scientists request the astronauts on the planet to describe what they see outside their spacecraft.

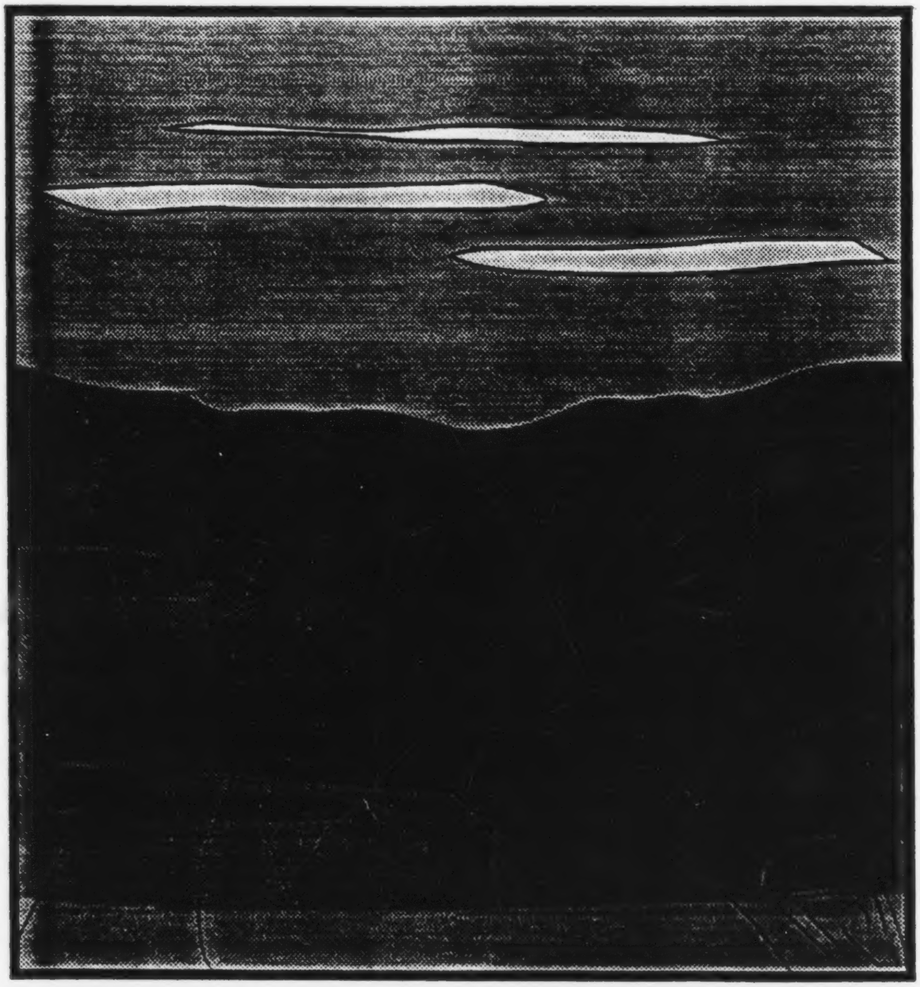
4. Give the designated Astronaut a copy of the picture of the Martian terrain. Instruct the astronaut to show it to no one.

5. The Astronaut begins the activity by verbally describing some of the things seen in the picture to the Communication Satellite. The description should be whispered so that none of the other team members can hear it. The Communication Satellite relays the description to the Tracking Station who in turn relays it to the Data Relay System or directly to Mission Control. While the first message is being received by Mission Control, the Astronaut sends more information until the entire picture is described.

6. As the descriptions are received by the Mission Control team member that person uses a pencil or marker pen to sketch a picture of the Martian terrain on a sheet of paper.
7. Conclude the activity by giving everyone a chance to compare the original picture with the one drawn by Mission Control.

Discussion:

Accurate communication is imperative for spaceflight. Much time and effort is wasted if communications are ambiguous. Critical mistakes can be made if messages are misunderstood. Consequently, NASA astronauts and mission controllers train extensively with each other before the actual mission to insure that each are fully fluent with terminology. To save time, many descriptive words and phrases are reduced to acronyms such as RMS for remote manipulator system, MECO for main engine cutoff, and PLSS for portable life support system.



Mars Horizon

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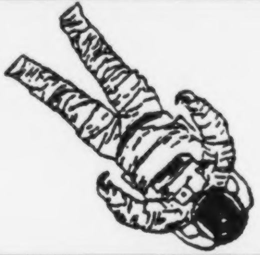
Classroom Activities



Pop Bottle Space Station

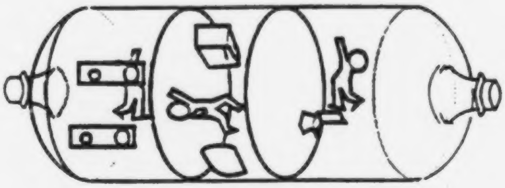
SUBJECT: Space Stations
TOPIC: Construction
DESCRIPTION: A large space station model is constructed out of two-liter plastic soda pop bottles and various hardware and scrap items.

MATERIALS and TOOLS:

Two-liter soda pop bottles (two per module)
Plastic hose connectors (from hardware store)*
Assorted dowel rods*
Plastic meat trays
Cellophane tape
Scissors
Razor blade knife
Miscellaneous "junk"

*Plastic hose connectors come in many sizes and shapes. Choose some that will either snugly fit inside the pop bottle pour spouts or fit around the outside. Sand paper or a file can be used to reduce the diameter of the pour spout to make the fit if necessary. Select dowel rods to fit the connectors to provide extensions for mounting solar panels, heat radiators, and antennas.

PROCEDURE:

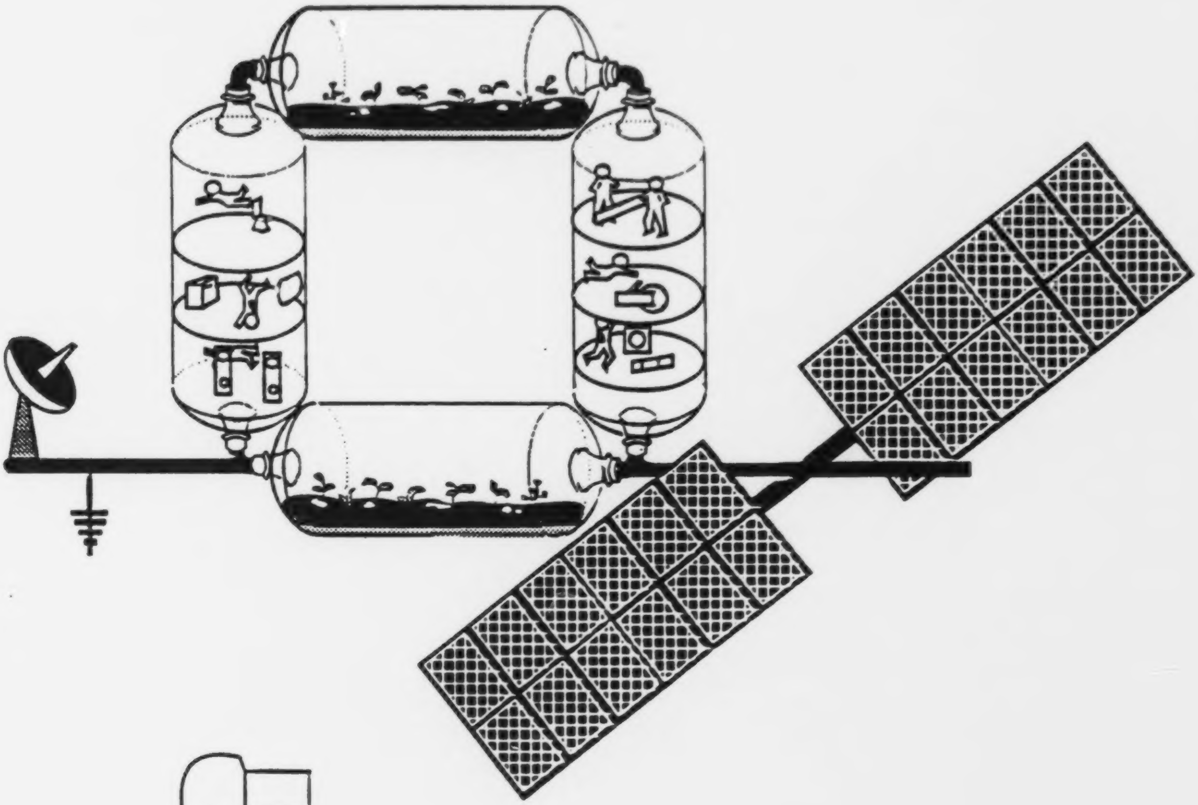


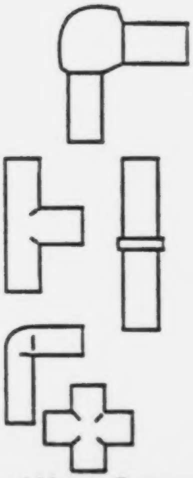
1. Cut the pour spout end off of one of the two pop bottles collected for each module as shown in the diagram. Tape this end to the rounded bottom of the other bottle so that the module appears to have two pour spouts. Make at least four modules per space station model.
2. Join the modules together in any design you wish with the hose connectors.
3. Add solar panels made from plastic meat trays, antennas from paper cups, the bottoms of soda pop cans, or anything else your students come up with.
4. To add extra interest to the model, cut doors in the modules with the razor blade knife and add furnishing to the modules. Partitions from plastic meat trays can be taped in place or held with glue. Small toy human figures can be added. Use one module as a terrarium. Add aquarium gravel to its bottom and cover with soil mixed with charcoal. Plant small-growing plants and water. Be careful not to over water. Shortly, water drops will condense on the walls of the bottle and run down the sides to form a mini hydrologic cycle.
5. Assemble the model on a table top or suspend with many strings from the ceiling.

DISCUSSION:

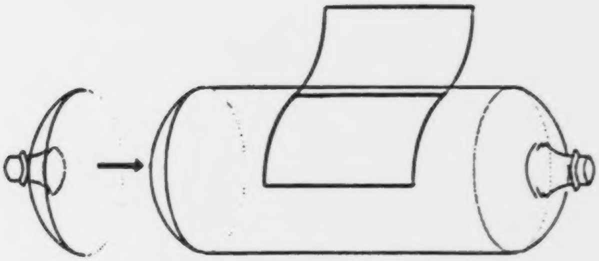
The soda pop bottle space station model is one of many variations of "junk" spacecraft model activities. Have students explain the design of their station to students in other classes and to parents during open house. Consider story-writing activities that explain how a real version of their station would be constructed in space and what would take place on board it.

Soda Pop Bottle Space Station





Typical Hose Connectors



Classroom Activities

Space Food Tray

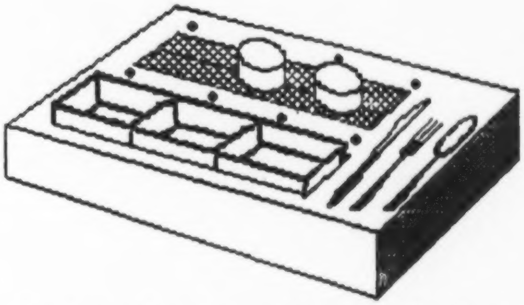
SUBJECT: Manned Space Flight
TOPIC: Food systems
DESCRIPTION: A working replica of the Space Shuttle food tray and food packages are made from a cardboard box and plastic freezer containers.
CONTRIBUTED BY: John Hartsfield, LeRC

MATERIALS:

Federal Express Overnight Box (or other cardboard box 18 X 12 X 3 inches in dimensions)
Plastic Canvas 13 X 6 inches (for needlepoint)
Silver foil wrapping paper (enough to cover the box)
8 Brass paper fasteners
Styrofoam sheet 18 X 12 X 2 inches
Liquid nail (or other glue that will bond styrofoam to cardboard)
Rubber cement
6 Velcro patches (from hardware or fabric store)
3 Pint size plastic freezer boxes
Cellophane tape
Plastic flatware (knife, fork, and spoon)
Assorted dry foods
Pudding or fruit cups (commercial food product in aluminum cans with pull-back lids)
Water

PROCEDURE:

1. Cut two rectangular openings in the box as shown in the picture. The openings should be just large enough to fit three plastic freezer boxes snugly.



2. Trim the styrofoam sheet to exactly fit the inside of the box.

3. Glue the styrofoam sheet to the inside of the box opposite the side the openings are cut. Close up the ends of the box and glue or tape them shut.

4. Carefully wrap the foil completely around the box and tape into place forming neat comers. The long seam should be positioned on the side opposite the openings. For a smoother finish, use rubber cement to bond the wrapping paper to the box.

5. Take a knife or scissors and cut the paper over the openings as shown in the diagram so that the paper will neatly fold around the edges and then tape it to the inside of the box.

6. Punch 8 holes as shown in the diagrams for the brass paper fasteners.

7. Cut the plastic canvas lengthwise and then cut two round holes just large

enough to hold the aluminum cans.

8. Attach the canvas to the inside of the box as shown in the diagram with the paper fasteners. Bend the fasteners to hold the canvas snugly.

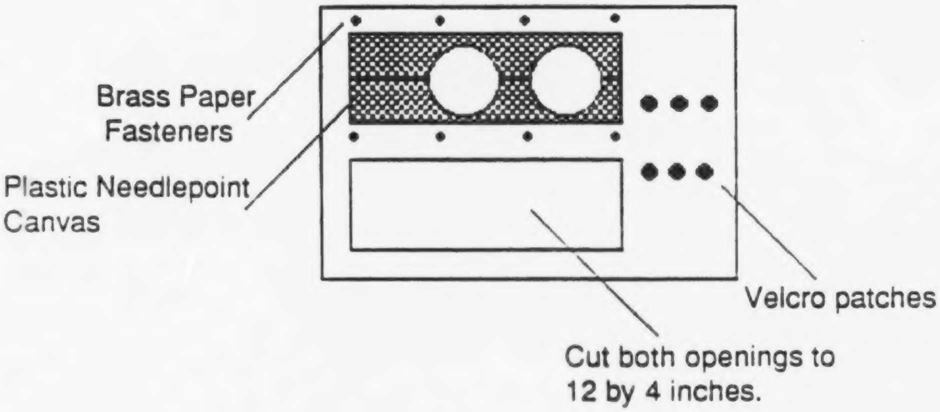
9. Attach velcro patches to the backs of the plastic flatware and the corresponding wool patches to the food tray as shown.

ACTIVITY IDEA:

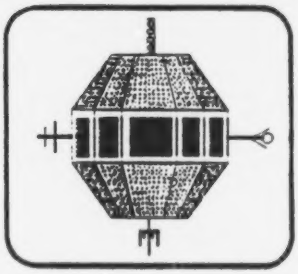
Make up several food trays and place various commercial food items in the freezer boxes. Use foods like dry soups, cereals, and freeze-dried fruits and vegetables. Many of these foods are available from supermarkets or from camping supply stores. Have your students prepare the foods with the addition of water and then simulate a meal in space. While eating the food, discuss problems astronauts might have eating in space. What happens to spills? How does the food stay in the food boxes? How do the astronauts clean up after their meal?

DISCUSSION:

The Space Shuttle food system is designed for convenience and versatility in the apparent weightless condition of Earth orbit. Once food items have been prepared by the addition of water and heating (if necessary), individual food boxes are inserted in the slots of the tray. The tray can then be mounted to one of the orbiter's cabin walls or strapped to a crew member's lap for stabilization and easy eating.


Brass Paper Fasteners
Plastic Needlepoint Canvas
Velcro patches
Cut both openings to 12 by 4 inches.

Classroom Activities



Robotic Activity

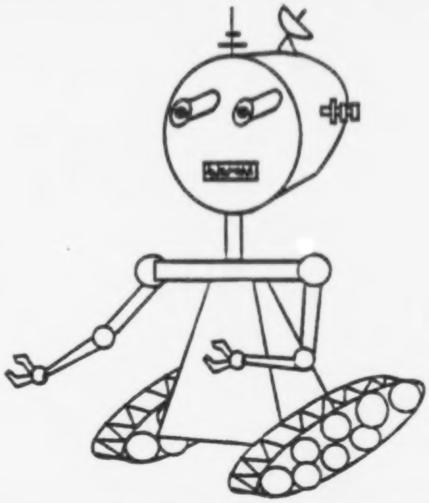
SUBJECT: Robotics
TOPIC: Communications
DESCRIPTION: Mittens and blindfold are placed on student to illustrate the fact of how challenging it is to program simple robotic moves.
CONTRIBUTED BY: Will Robertson, MSFC

MATERIALS:

Two mittens
Blindfold
Two sticks
Bell or whistle
Two-liter plastic soda pop bottle (empty)

PROCEDURE:

1. Select two students from the class. Assign one student the role of the robot while the other student the role of "brain."
2. Place mittens on the hands (end effectors) of the "robot" and blindfold the robot's eyes.
3. Instruct the class to come up with a simple code (language) that the robot will be able to understand. For example, sounds made when two sticks are clicked together. When the sticks are struck twice, this could mean that the student-robot can move forward two steps. Using a bell before the sticks are struck could signal the robot to turn right or left before moving. The code should include commands for forward, right, left, stop, reach, up, down, and grasp.
4. On a nearby table, place an unbreakable object, such as a plastic 2-liter soda pop bottle which can be picked up by the student-robot.
5. The student assigned as the "brain" will signal (by using the code developed) the robot to pick up object on table.
6. Let other students play the roles of robot and brain. Determine how easy or difficult it is for the student-robot to accomplish its mission.

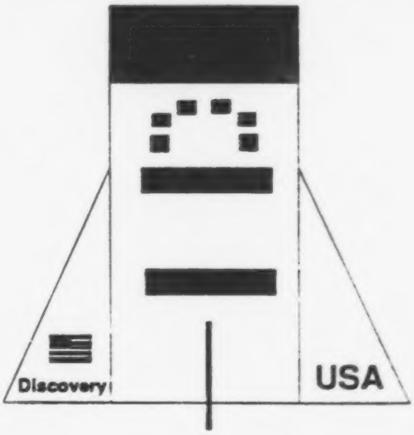


DISCUSSION:

This activity is used to illustrate what is involved in programming a robot to interact with its environment. Have students discuss how robots are programmed to do different tasks in industry. For example, how are robots used in mining, oceanography, automobile industry, and space exploration?

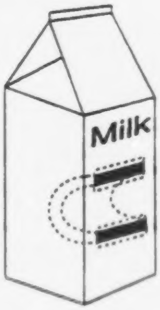
Classroom Activities

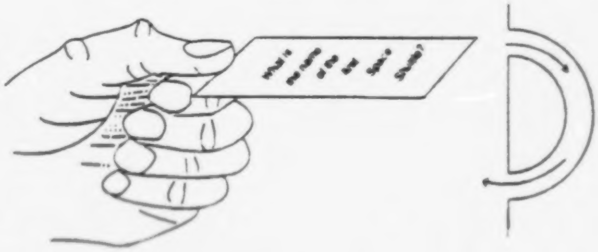
Shuttle Chute



SUBJECT: Manned Spaceflight, etc.
TOPIC: A simple question and answer device is constructed for or by elementary students.
DESCRIPTION: Students try to answer questions on cards and then read answers on the card backs after the cards have been fed through the Shuttle Chute.
CONTRIBUTED: Janifer Mayden, NASA HQ

MATERIALS:
Half gallon milk carton (paper)
Tape
File cards
File folder
Scissors
Decoration materials





PROCEDURE:
1. Cut open one side of the milk carton to access its interior.
2. Cut two rectangular openings in the other side of the carton as shown in the diagrams.
3. Cut two strips of heavy paper from the file folder and bend them into semicircles. Fold the ends of the paper to form tabs for taping. The strips should be wider than the rectangular holes cut in step 2. One strip should be longer than the other as shown in the diagrams.
4. Tape the strips around the rectangular holes as shown in the diagram.
5. Seal the back of the milk carton and decorate the milk carton to look like a Space Shuttle.
6. Make up a few dozen question cards about the Space Shuttle or any other outer space topic you choose. Write the questions on one side of each card and the answers on the other.

Using The Shuttle Chute

Students should read the questions on the cards and try to answer them. Each card is slipped into the top rectangular hole. The heavy paper strips inside bend the card and invert it before it comes out the lower rectangular hole. The answer to the question becomes visible as the card leaves the chute.

Classroom Activities

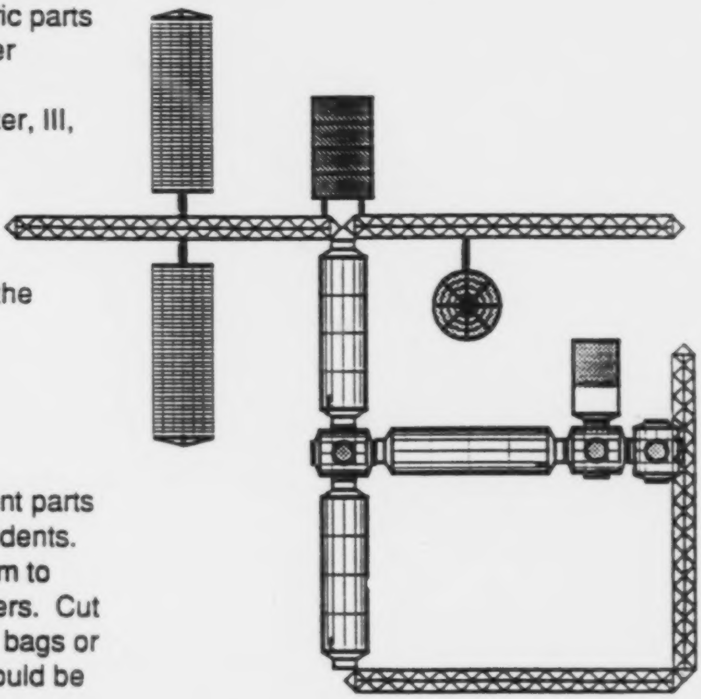
Space Station Communications Exercise

SUBJECT: Communications and Space Station
TOPIC: Designing a layout for a space station design and communicating this information accurately to a colleague.
DESCRIPTION: Students attempt to build matching space stations from generic parts while communicating with each other through verbal channels only.
CONTRIBUTED: Dr. Harry B. Herzer, III, HQ

MATERIALS:
Space station component parts
Zip-lock bags or envelopes to hold the component parts
Glue
Scissors

PROCEDURE:

1. Copy the space station component parts to make enough sets for your students. Reinforce the parts by gluing them to heavy paper such as old file folders. Cut out the pieces and place them in bags or envelopes. Each set of parts should be identical.
2. Divide your students into groups of two or four students each. Split each group in half into subgroups and give each a set of space station components.
3. One subgroup begins the activity by laying out the component parts and arranging them into a space station of their design. The other subgroup should be positioned so that they cannot see the design.
4. The first subgroup then tries to get the second subgroup to duplicate the space station design by giving them verbal instructions only.



5. After the second station has been created, permit both groups to compare their efforts.
6. Reverse roles and tell the second subgroup to design a station and verbally

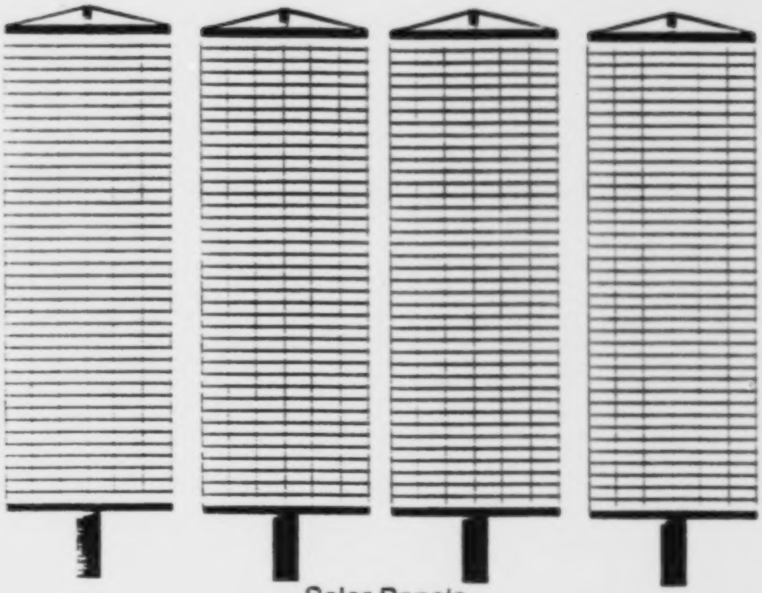
communicate the design to the first.

7. (optional) To assist in preparing students for this activity, you may wish to make view graphs of the station modules to demonstrate what will be required.

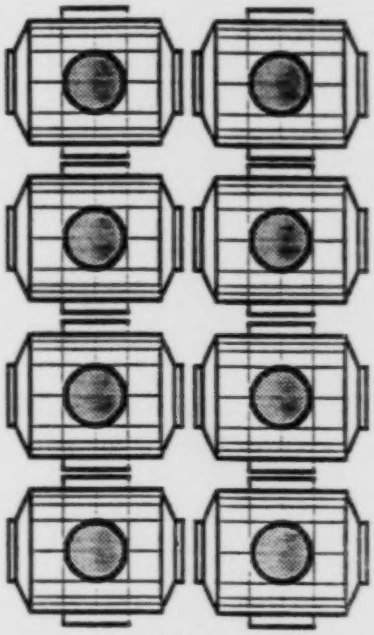
DISCUSSION:

This activity provides an excellent introduction to the problems of spaceflight communication. When only words are permitted, as in radio communications, they have to be very precise. Students will discover, as they become more experienced with the activity, that they will be creating words to describe components of the space stations they are building. Not only do the words used have to be precise but the directions also. Statements like "take the thingamajig and place it right over there" are meaningless. More precise and useful are statements such as "position the module so that its right end is in direct line with the left end of the module you placed down before."

As an interesting variation of the activity, imagine the two subgroups are located great distances apart such as on Earth and in orbit about Mars. Under such a circumstance, cross communication is very difficult. An instruction by radio takes 20 minutes to get to Mars. A question regarding that instruction will take another 20 minutes to get back to Earth and still another 20 minutes for the answer to return. Unless communications are very precise, much time will be wasted.



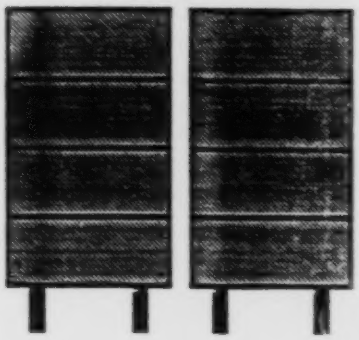
Solar Panels

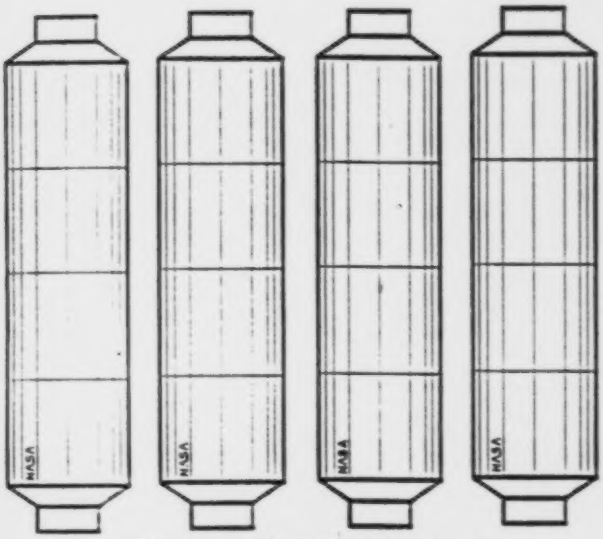


Nodes

Antenna

Thermal Radiators

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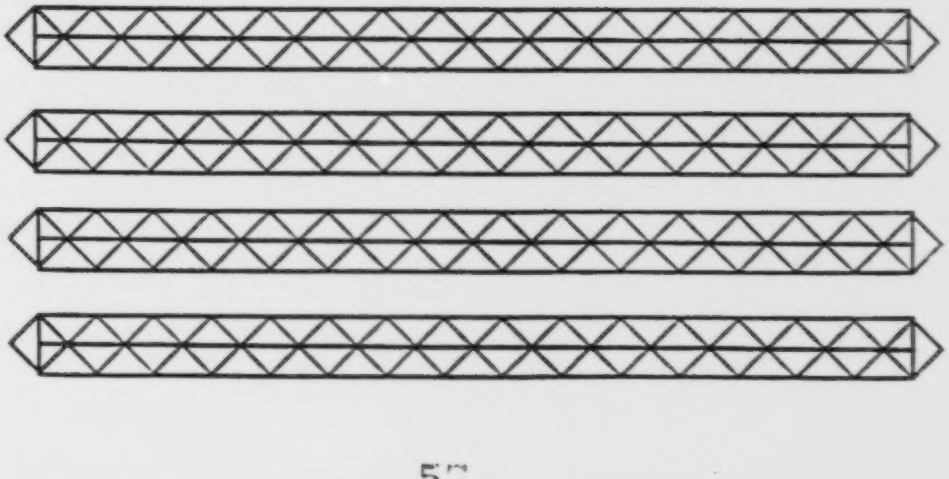
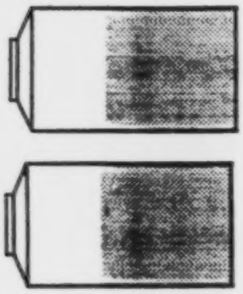
Habitat and Laboratory Modules

Truss Beams

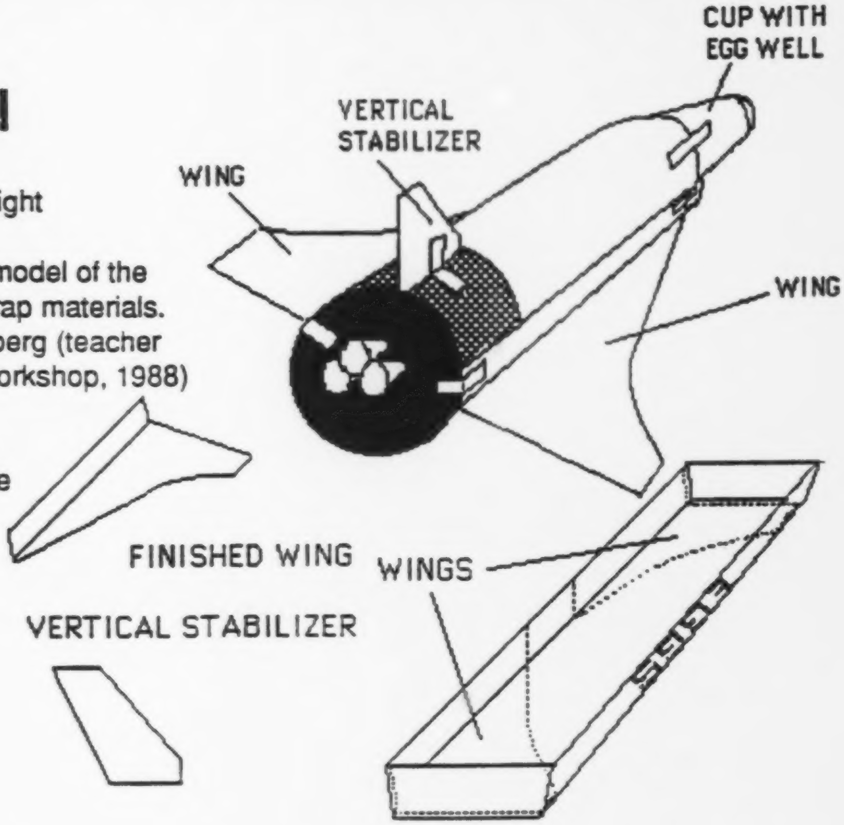




Service Modules

Classroom Activities

Junk Space Shuttle Model



SUBJECT: Manned Space Flight
TOPIC: Model building
DESCRIPTION: Construct a model of the Space Shuttle orbiter from scrap materials.
CONTRIBUTED BY: Joy Eulberg (teacher in OSU summer aerospace workshop, 1988)

MATERIALS and TOOLS:
1 2-liter plastic soda pop bottle
2 egg cartons
1 6-oz paper cup
Masking tape
Newspaper
Glue for paper maché
White glue
Scissors

PROCEDURES:

1. Cut two wings from the top of an egg carton as shown in the diagrams. Tape the wings, as shown, to the bottle.

2. Cut out an "egg well" from the carton and tape to the bottom of the cup to round off the flat surface. Tape the cup over the neck of the bottle. If the neck is too long to permit a good fit, take a sharp knife and trim off a bit.

3. Cut out a vertical tail for the model from the egg carton and tape on to the bottle.

4. Cover the model with paper maché. Narrow strips of newspaper are easiest to work with. Let the paper maché dry and add additional layers for strength.

5. Cut three egg wells to make engines for the orbiter. Cover each well with paper maché and let dry.

6. When the body of the orbiter and the engines are dry, glue the engines to the tail end of the model as shown.

7. Paint the model and add decals, stars, and other decorations when dry.

Soda Pop Can Hero Engine

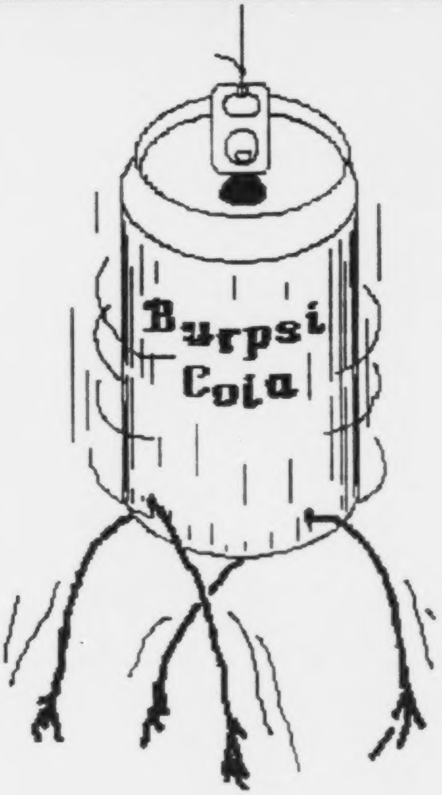
SUBJECT: Rocketry
TOPIC: Newton's Laws of Motion
DESCRIPTION: Water streaming through holes in the bottom of a suspended soda pop can causes the can to rotate.
CONTRIBUTED BY: Tom Clausen, KSC Explorations Station

MATERIALS AND TOOLS:
Empty soda pop can with the opener lever intact
Nail or ice pick
Fishing line
Bucket or tub of water

METHOD:

1. Lay the pop can on its side and using the nail or ice pick carefully punch four equally spaced small holes just above and around the bottom rim. Then before removing the punching tool for each hole, push the tool to the right (parallel to the rim) so that the hole is slanted in that direction.
2. Bend the can's opener lever straight up and tie a short length of fishing line to it.
3. Immerse the can in water until it is filled. Pull the can out by the fishing line. Water streams will start the can spinning.

DISCUSSION:



The Soda Pop Can Hero Engine is an excellent demonstration of Newton's Laws of Motion. The can rotates because a force is exerted by the flowing water (1st. Law). The rate of rotation will vary with different numbers of holes and different diameters of holes in the can (2nd. Law). Try two holes and try a can with large holes verses a can with small holes. The can rotates in the opposite direction from the direction of the water streams (3rd. Law).

For more information about Hero engines, refer to Classroom Activities, pp 9-10, *Aviation and Space Education News*, March, 1988.

Classroom Activities

ROCKET PINWHEEL

SUBJECT: Rocketry
TOPIC: Action-Reaction Principle
DESCRIPTION: Construct a balloon-powered pinwheel.
CONTRIBUTED BY: John Hartsfield, LeRC

MATERIALS:

Wooden pencil with an eraser on one end
sewing pin
Round party balloon
Flexible soda straw
Plastic tape

METHOD:

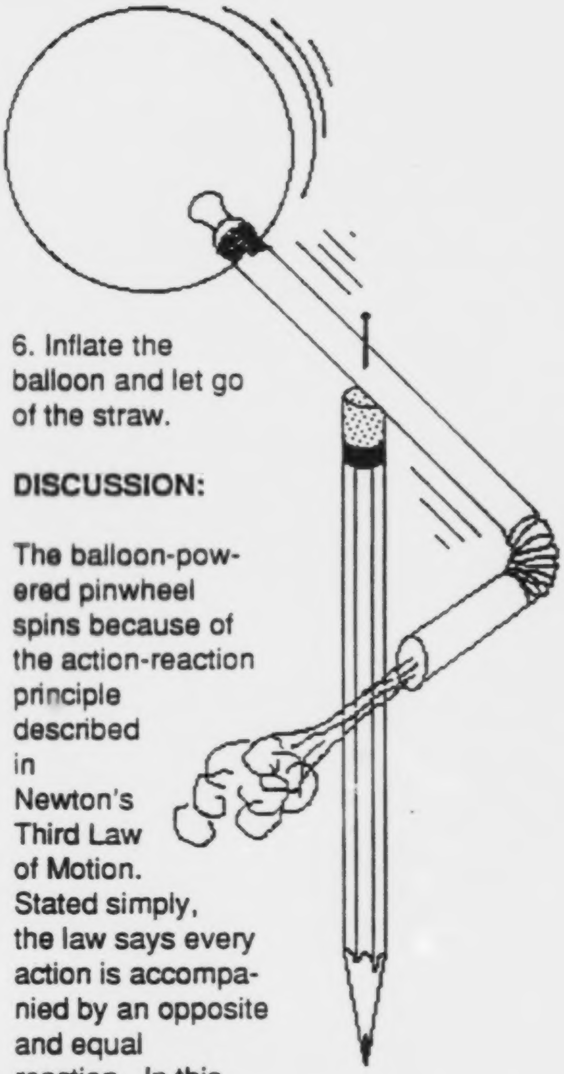
1. Inflate the balloon to stretch it out a bit.

2. Slip the nozzle end of the balloon over the end of the straw farthest away from the bend. Use a short piece of plastic tape to seal the balloon to the straw. The balloon should inflate when you blow through the straw.

3. Bend the opposite end of the straw at a right angle.

4. Lay the straw and balloon on an outstretched finger so that it balances. Push the pin through the straw at the balance point and then continue pushing the pin into the eraser of the pencil and finally into the wood itself.

5. Spin the straw a few times to loosen up the hole the pin has made.



6. Inflate the balloon and let go of the straw.

DISCUSSION:

The balloon-powered pinwheel spins because of the action-reaction principle described in Newton's Third Law of Motion. Stated simply, the law says every action is accompanied by an opposite and equal reaction. In this case, the balloon produces an action by squeezing on the air inside causing it to rush out the straw. The air, traveling around the bend in the straw, imparts a reaction force at a right angle to the straw. The result is that the balloon and straw spins around the pin.

Classroom Activities

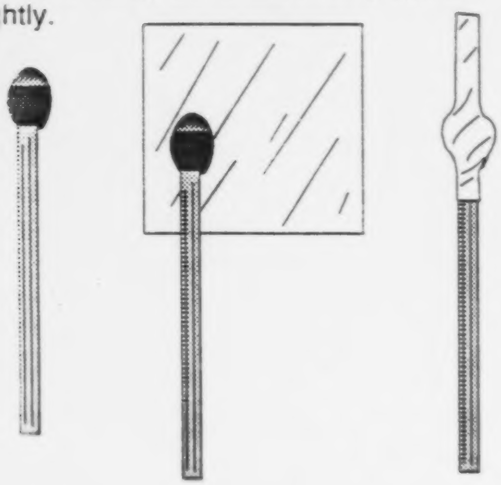
Match Stick Rocket

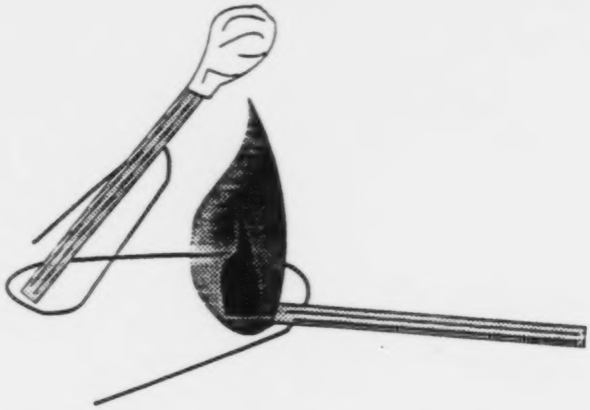
SUBJECT: Rocketry
TOPIC: Propulsion
CONTRIBUTED BY: Steve Culivan, KSC
DESCRIPTION: A small solid propellant rocket is made from a match and a piece of aluminum foil.

MATERIALS:
2 match book matches or wooden stick matches
Small square of aluminum foil
Paper clip
Safety pin

PROCEDURE:

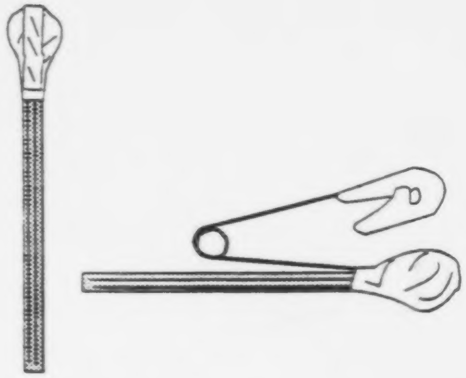
1. Take one match and wrap a small piece of aluminum foil around the match-head. Wrap the foil tightly.
2. Make a small opening in the foil wrapped around the match head by inserting the point of a safety pin and bending upward slightly.





3. Bend the paper clip to form a launch pad as shown in the diagrams. Erect the match stick rocket on the pad. Make sure the pad is set up on a surface that will not be damaged by the rocket's exhaust such as a lab table.
4. Ignite the match by holding a second lighted match under the foil until its combustion temperature is reached.

Caution: Be sure the match rocket is pointed away from people or burnable materials. It is recommended to have water or some other fire extinguishant available. The foil head of the rocket will be very hot!



DISCUSSION:
The match stick rocket demonstrates Isaac Newton's Laws of Motion as they relate to rocketry. Newton's third law states that for every action, there is an opposite and equal reaction. The exhaust of the fire products from the burning match (smoke and gas) is the "action" and the movement of the rocket in the other direction is the "reaction." The action thrust is produced when the match burns in an enclosed environment. The aluminum foil acts as a rocket combustion chamber. Because the opening in the foil is small, pressure builds up in the chamber that eventually escapes as a rapid stream of smoke and gas.

In an interesting variation of the experiment, try making holes of different diameters to let the combustion products out at different rates. A larger opening permits the smoke and gas to escape before it has time to build up much pressure. The escape of the products will be slower than produced by a match stick rocket with a smaller opening. Isaac Newton's second law states that the force or thrust of a rocket is equal to the mass of the smoke and gas escaping the rocket times how fast it escapes. In this experiment, the mass of the smoke and gas is the same for both cases. The difference is in how fast it escapes. Compare the distance traveled with the two match stick rockets.

Classroom Activities

Pencil Rockets

SUBJECT: Space Flight
TOPIC: Rockets
DESCRIPTION: Rockets, using pencils for their bodies, are launched with a rubber band-powered launch platform.
CONTRIBUTED BY: Gregory Vogt, OSU

MATERIALS and TOOLS:

2 Pieces of wood 3'X4"X1" in size
2 Cup hooks
1 Wooden spring clothes pin
1 Small wood screw
1 Screw eye
2 Metal angle irons and screws
4 Feet of heavy string
Iron bailing wire
Several rubber bands
Several wooden pencils
Several pencil cap erasures
Cellophane or masking tape
Heavy paper
Saw
Wood file
Drill (3/16 inch diameter)
Pliers

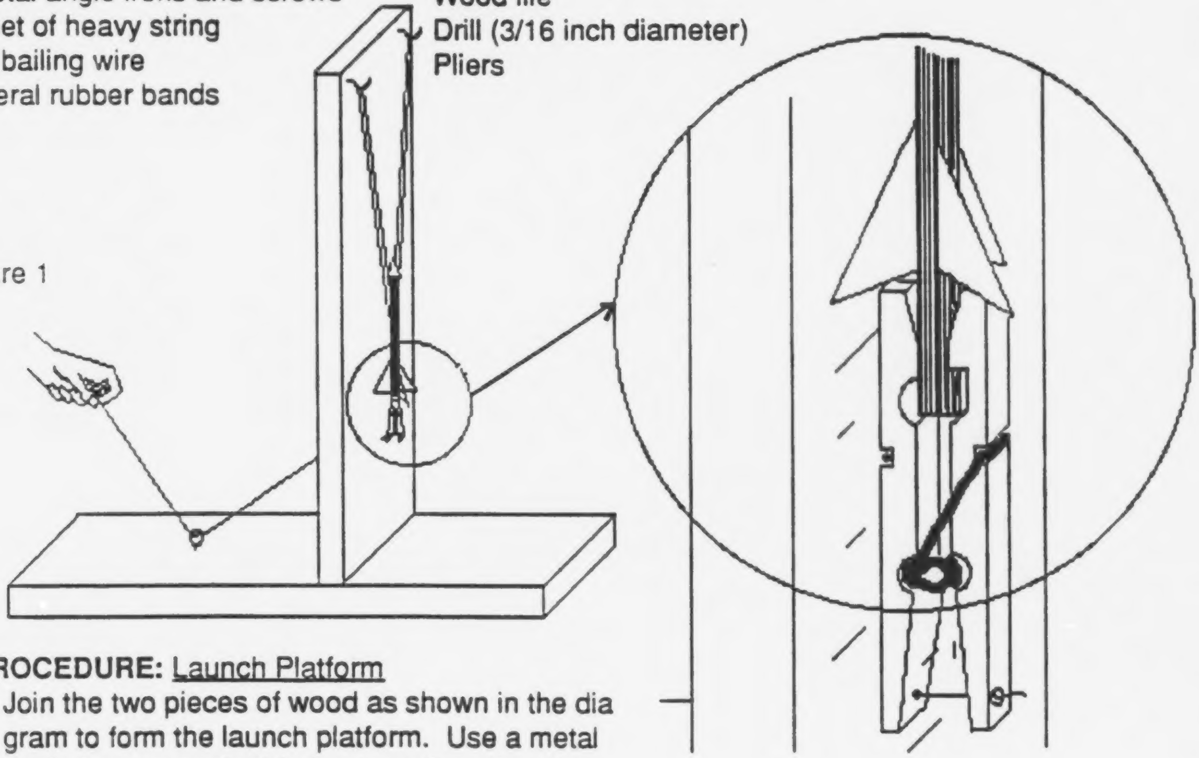


Figure 1

PROCEDURE: Launch Platform

1. Join the two pieces of wood as shown in the diagram to form the launch platform. Use a metal angle iron on each side to strengthen the structure.
2. Screw in the cup hooks and screw eye into the wood in the places indicated in figure 1.

3. Temporarily separate the wooden pieces of the clothes pin and file the "jaw" of one piece square as shown in figure 2. Drill two holes through the other wood piece as shown. Drill one hole through the first wood piece as shown.
4. Drill a hole through the upright piece of the launch platform as shown and screw the clothes pin to it so that the lower hole in the pin lines up with the hole in the upright. Reassemble the clothes pin.
5. Tie a knot in one end of the string and feed it through the clothes pin as shown in figure 1, through the upright piece of the platform and then through the screw eye. When the free end of the string is pulled, the clothes pin will open. The clothes pin has become a rocket hold-down and release device.

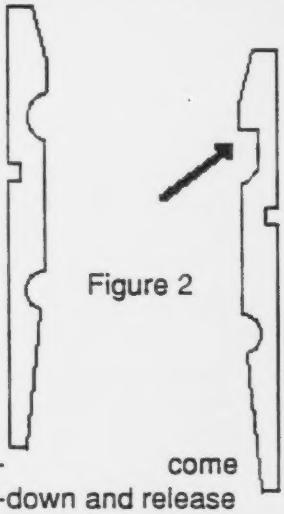


Figure 2

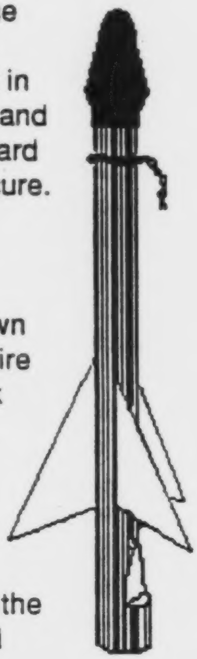
6. Loop four rubber bands together and loop their ends on the cup hooks. The launch platform is now complete.

Rocket

1. Take a short piece of bailing wire and wrap it around the erasure end of the pencil about one inch from the end. Use pliers to twist the wire tightly so that it "bites" into the wood a bit. Next, bend the twisted ends into a hook as shown in figure 3.
2. Take a sharp knife and cut a notch in the other end of the pencil as shown in figure 4.
3. Cut out small paper rocket fins and tape them to the pencil just above the notch.
4. Place an erasure cap over the upper end of the rocket. This blunts the nose to make the rocket safer if it hits something. The rocket is now complete.

Launching Pencil Rockets

1. Choose a wide open area to launch the rockets.
2. Spread open the jaw of the clothes pin and place the notched end of the rocket in the jaws. Close the jaws and gently pull the pencil upward to insure the rocket is secure. If the rocket doesn't fit, change the shape of the notch slightly.
3. Pull the rubber bands down and loop them over the wire hook. Be sure not to look down over the rocket as you do this in case the rocket is prematurely released.
4. Stand at the other end of the launcher and step on the wood to provide additional support.



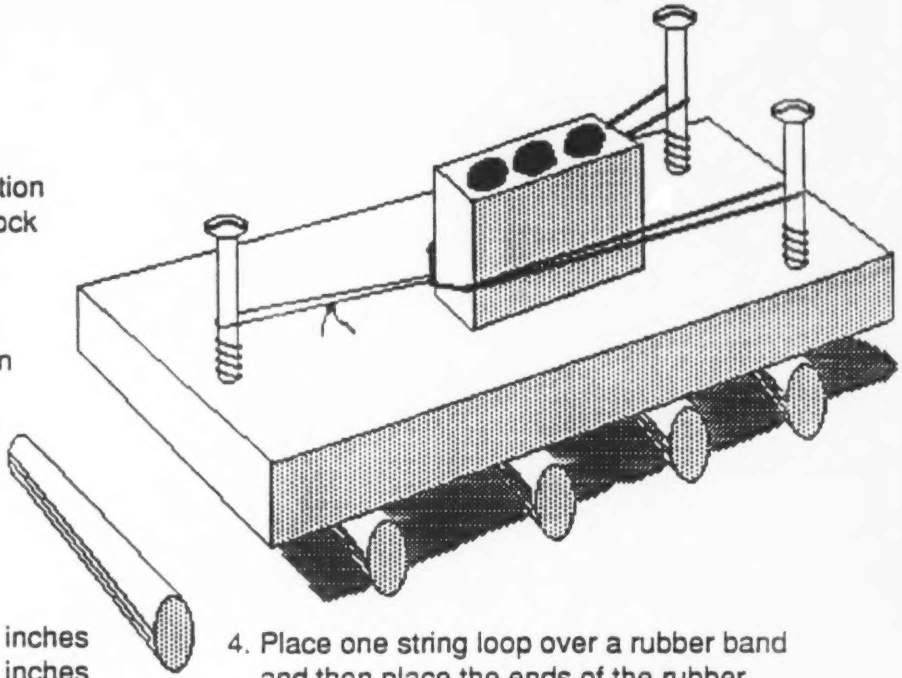
5. Make sure no one except yourself is standing next to the launch pad. Count down from 10 and pull the string. Step out of the way from the rocket as it flies about 75 feet up in the air, gracefully turns upside down and returns to Earth.
6. The rocket's terminal altitude can be adjusted by increasing or decreasing the tension on the rubber bands.

Discussion

Like the flight of Robert Goddard's first liquid fuel rocket in 1926, the pencil rocket gets its upward thrust from its nose area rather than its tail. Regardless, the rocket's fins still provide stability, guiding the rocket upward for a smooth flight. If a steady wind is blowing during flight, the fins will steer the rocket towards the wind in a process called "weather cocking." On NASA rockets, active controls steer during flight to prevent weather cocking and to aim them on the right trajectory. Active controls include tilting nozzles and various forms of fins and vanes.

Classroom Activities

Newton Cart



SUBJECT: Rocketry
TOPIC: Newton's Laws of Motion
DESCRIPTION: A wooden block is thrown by a slingshot-like device from a cart, placed on rollers, and produces a thrust that causes the cart to move in the opposite direction.
CONTRIBUTED BY: Gregory Vogt, OSU (Classic AESP activity)

MATERIALS and TOOLS:

1 wooden block about 4X8X1 inches
1 wooden block about 3X2X1 inches
3 3-inch by 10 wood screws (round head)
12 round pencils or short lengths of similar dowel rods
3 rubber bands
cotton string (several feet)
matches
6 lead fishing sinkers (about 1/2 ounce each)
Drill and bit
Vice
Screw driver

PROCEDURE:

1. Screw the three screws in the large wood block as shown in the figure.
2. Hold the short piece of wood with a vice and drill three holes large enough to drop two sinkers in each.
3. Tie several small loops of string (the same size).
4. Place one string loop over a rubber band and then place the ends of the rubber band over the two screws on one end of the large wood block. Pull the rubber band back like a slingshot and slip the string over the third screw to hold the rubber band stretched.
5. Arrange the pencils or dowel rods in a row like railroad ties on a level table top. Set the large block on one end of the row so that the single screw points to the middle of the row. Slip the small block (without sinkers) into the rubber bands.
6. Light a match and ignite the ends of the string hanging down from the loop. When the string burns through, the rubber band will throw the block off the cart and the cart will roll in the other direction. Note how far the cart travels along the table top.
7. Reset the equipment and add a second rubber band. Again, light the string and note how far the cart travels.

8. Reset the equipment and try again with 3 rubber bands. Try again with one rubber band and two sinkers, 4 sinkers, etc.

DISCUSSION:

The Newton Cart provides an excellent demonstration of Isaac Newton's three laws of motion. The laws are stated in general terms below.

First Law:	An object at rest will remain at rest or an object in motion will remain in motion in a straight line unless acted upon by an unbalanced force.
Second Law:	Force equals mass times acceleration.
Third Law:	For every action there is an opposite and equal reaction.

The Newton Cart remains at rest on the table top until an unbalanced force (from the expelled block) causes it to move. Rockets remain on the launch pad until the thrust from the engines propel it upward.

The amount of thrust on the cart is determined by the mass of the block and how fast it is thrown off. This can easily be seen in how far the cart traveled. The cart with a single rubber band and no sinkers did not travel very far. With two and three rubber bands, the block was thrown off much faster (acceleration). With sinkers added to the block, the block had more mass and this caused the cart to travel farther than when the block had no sinkers at all. In rockets, the propellants provide the mass and the rocket engine burns the propellants and directs the gases produced in the proper direction. Rockets can increase their thrust by burning propellants faster (mass) and by expelling the gases produced out the engine more (acceleration).

Throwing the block from the cart is an "action" and the cart's movement is a "reaction." The action and reaction are in opposite directions. Rockets produce action, or thrust, by the escape gases out their engines. The rocket's movement in the opposite direction is its reaction.

Classroom Activities

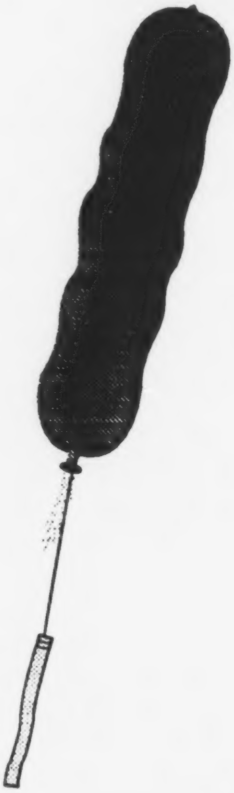
Balloon Rocket

SUBJECT: Rocketry
TOPIC: Stability
DESCRIPTION: A long balloon is stabilized in flight with a string and a paper streamer.
CONTRIBUTED BY: Adapted from a 1953 *Air Trails* article.

MATERIALS:
Long party balloon
String
Paper napkin
Scissors
Cellophane tape

PROCEDURE:

1. Take about a two or three-foot-long length of string and a loop at one end around the nozzle of the balloon. The loop should be large enough to provide a strong "rocket thrust" when the balloon is inflated and released.
2. Cut a 1 to 2-inch-wide strip of paper from the napkin to form a streamer.
3. Use a short piece of tape to attach the other end of the string to the paper streamer.
4. Inflate the balloon and point in the desired direction. The balloon should fly in more or less a straight path.
5. Adjust the length of the string and the size of the streamer to achieve the best flights.
6. Compare the flight of the stabilized balloon with the flight of an unstabilized balloon.



DISCUSSION:
Due to the action-reaction principle (Newton's Third Law of Motion), an inflated balloon flies as a rocket when its nozzle is released. Normally, the flight is erratic and the balloon tumbles wildly. By attaching a string with a streamer to the balloon, the balloon's flight is stabilized. The streamer and string provides drag, which is a force in the opposite direction from the thrust produced by the air rushing out the balloon's nozzle. This drag prevents the balloon from tumbling by keeping the nozzle pointed more or less towards the rear during flight.

Classroom Activities

Balloon Staging

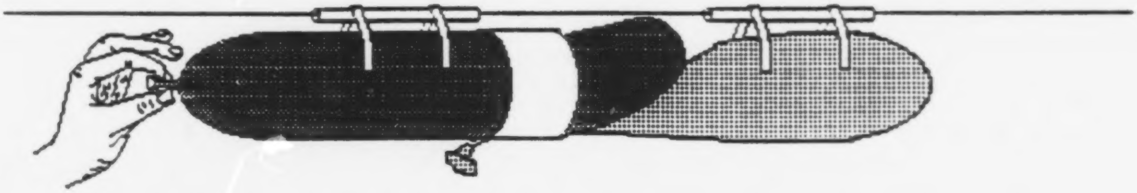
SUBJECT: Rocketry
TOPIC: Rocket staging
DESCRIPTION: Two inflated balloons simulate a multistage rocket launch as they slide along a fishing line on the thrust produced by escaping air.
CONTRIBUTED BY: Gregory Vogt, OSU
(Classic AESP activity)

MATERIALS and TOOLS:

2 long party balloons
Nylon monofilament fishing line (any weight)
2 Plastic straws (milkshake size)
Styrofoam coffee cup
Masking tape
Scissors

PROCEDURE:

1. Thread the fishing line through the two straws. Stretch the fishing line snugly across a room and secure its ends. Make sure the line is just high enough for people to pass safely underneath.
2. Cut the coffee cup in half so that the lip of the cup forms a continuous ring.
3. Loosen the balloons by preinflating them. Inflate the first balloon about 3/4 full of air and squeeze its nozzle tight. Pull the nozzle through the ring. While someone assists you, inflate the second balloon. The front end of the second balloon should extend through the ring a short distance. As the second balloon inflates, it will press against the nozzle of the first balloon and take over the job of holding it shut. It may take a bit of practice to achieve this.
4. Take the balloons to one end of the fishing line and tape each balloon to a straw. The balloons should be pointed along the length of the fishing line.



5. If you wish, do a rocket countdown and release the second balloon you inflated. The escaping gas will propel both balloons along the fishing line. When the first balloon released runs out of air, it will release the other balloon to continue the trip.

DISCUSSION:

Travel into outer space takes enormous amounts of energy. Much of that energy is used to lift rocket propellants that will be used for later phases of the rocket's flight. To eliminate the technological problems and cost of building giant one-piece rockets to reach outer space, NASA, as well as all other space fairing nations of the world have chosen to use a rocket technique that was invented by 16th-century fireworks maker Johann Schmidlap. To reach higher altitudes with his aerial displays, Schmidlap attached smaller rockets to the top of larger ones. When the larger rockets were exhausted, the smaller rocket climbed to even higher altitudes. Schmidlap called his invention a "step rocket."

Today's space rockets make use of Schmidlap's invention through "multistaging." A large first stage rocket carries the smaller upper stages for the first minute or two of flight. When the first stage is exhausted, it is released to return to the Earth. In doing so, the upper stages are much more efficient and are able to reach much higher altitudes than they would have been able to do simply because they do not have to carry the expired engines and empty propellant tanks that make up the first stage. Space rockets are often designed with three or four stages that each fire in turn to send a payload into orbit.

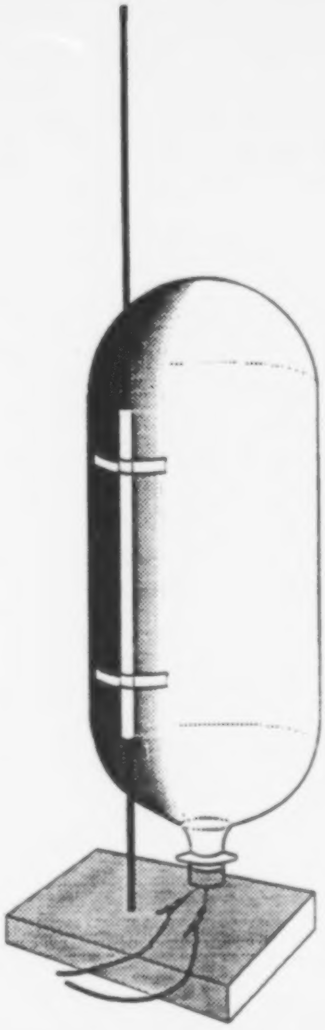
Classroom Activities

Liquid Bottle Rocket

Subject: Rocketry
Topic: Liquid propelled rocket.
Description: A flyable liquid-propelled rocket is made from a plastic 2 liter soda pop bottle.
Contributed By: Gregory Vogt, OSU

Materials:
Plastic 2 liter soda pop bottle
Spray mist bottle
Model rocket igniters
Model rocket launch pad with electric control
Fat soda straw
Lighter fluid (naptha)
Masking tape
Hammer
Fat nail 1/8" in diameter
Wood block

Refer to cautions in the discussion section.



Procedure:

1. Remove the plastic flat bottom from the 2 liter bottle. The black plastic is glued on and can be removed by pulling it off. It may be helpful to use scissors to cut it a bit in order to get a grip. Do not puncture the bottle.
2. Tape the soda straw along the side of the bottle to form a launch lug like those used in model rockets.
3. Remove the bottle cap and pound a nail hole from the inside to form a rocket nozzle. Use the wood block as a surface to hammer into. The hole should be about 1/8" in diameter.
4. Set up the launch pad in an open area about the size of a back yard.
5. Transfer enough lighter fluid from the container to the spray mist bottle to enable the bottle to work. **Spray the lighter fluid a few times into the air away from open flame or other ignition sources to**

get a uniform spray.

6. Remove the bottle cap and spray lighter fluid 1 or 2 times (no more) into the bottle. Replace the cap and thread the bottle's straw with the launch pad's launch rod.
7. Insert an electric igniter into the nozzle so that the igniter head enters the chamber where the lighter fluid mist is. Be careful not to squeeze the igniter wires together to cause a short circuit. Normally, the plastic liner of the cap is sufficient to prevent short circuits with the cap metal.
8. Do a brief countdown and ignite the rocket. Use a second rocket if you wish to have another flight. The first rocket needs time for fresh air to replace residual combustion gasses.

Discussion:

Upon ignition, the liquid propellant bottle rocket rises about 15 to 20 feet into the air with a very audible whoosh from the rocket's exhaust. Because the lighter fluid or naptha has been converted into a fine spray, much of the fluid in the bottle ignites immediately. Each tiny droplet of naptha provides a large burning surface for its volume consequently making ignition much more rapid than would have taken place if large drops of naptha were ignited.

The liquid propelled space rocket works on this very principle. Liquid propellants from tanks inside the rocket casing are pumped to the combustion chamber of the engine. Injectors, the rocket equivalent of shower spray nozzles, spray combustible mixtures of the propellants into the chamber where they are ignited. The rapid burning of the spray produces high gas pressure inside the chamber because of the expansion of the gas products during combustion. The expanded gas escapes through the engine nozzle and creates a powerful thrust.

The liquid propelled bottle rocket rises quickly off the launch pad to an altitude of as much as 20 feet before drag with the air produces a tumbling motion and stops its upward progress. After the first flight the bottle is crumpled because the plastic is heated, but not burned through, by the combustion inside. Cool outside air cannot flow back into the bottle as quickly as the combustion products that left through the nozzle. Outside air pressure squeezes the bottle and creates permanent dents. The bottle is still usable for several flights because additional ignitions reshape the bottle as pressure inside increases.

Caution: As with any demonstration involving fire, be careful to keep away from the rocket a safe distance before igniting it. A distance of 10 feet is sufficient. Do not over pressurize the bottle by spraying more than 2 times per launch or experimenting with smaller diameter nozzle holes. If the rocket does over pressurize, the aluminum bottle cap will be blown off the bottle downward with a startling sound. The bottle itself is surprisingly strong. Discard the rocket and make a new one. It is recommended that students not be told what the liquid propellant is. Refer to it as "special rocket fuel only teachers can get."

Classroom Activities

Water Rockets

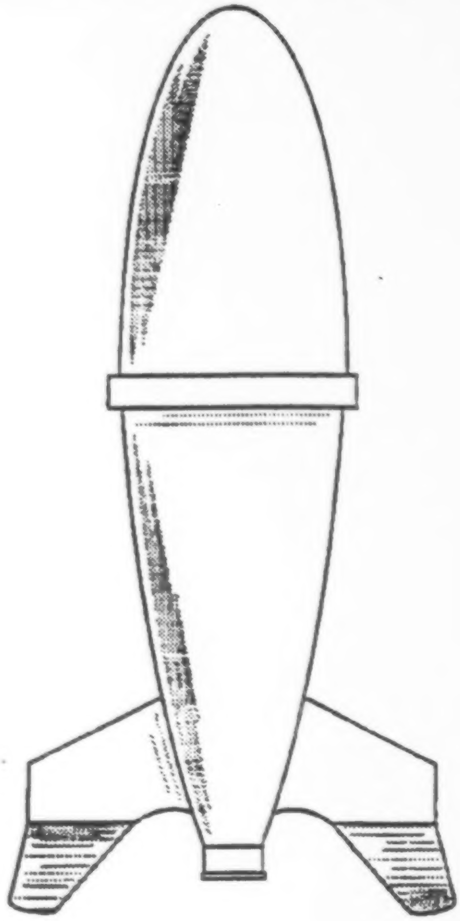
SUBJECT: Rockets
TOPIC: Newton's second law of motion is demonstrated.
DESCRIPTION: Varying the amount of water and pressure in water rockets affects the distance they travel.
CONTRIBUTED BY: Gregory Vogt, OSU

MATERIALS AND TOOLS:

2 Water rockets and pumps (available for a few dollars each from toy stores)
Water
Small wooden stakes, small flags, or other materials to serve as markers

PROCEDURE:

1. Take the water rockets, pumps, water supply, and markers to an outside location such as a clear, grassy playing field.
2. Attach both rockets to their pumps as shown on the package they came in. Pump one rocket 10 times. Pump the second rocket 20 times. Have two students point the rockets across the field in a direction in which no one is standing. The rockets should be held next to each other at exactly the same height above the ground and aimed upward at about a 45 degree angle. Count backwards from 3 and have the students release the rockets. Mark the distance each rocket flew.
3. Pour water into one rocket so that if fills up to the 100 ft line. Do not pour water into the other rocket. Attach both rockets to their pumps. Pump both rockets 20 times. Again aim the rockets across the field as before and release them simultaneously. Mark the distance each rocket flew. (Caution: The rocket with the water will expel the water from its chamber and may spray the students. If the student stands to the side for the release, the water spray should miss the student.)

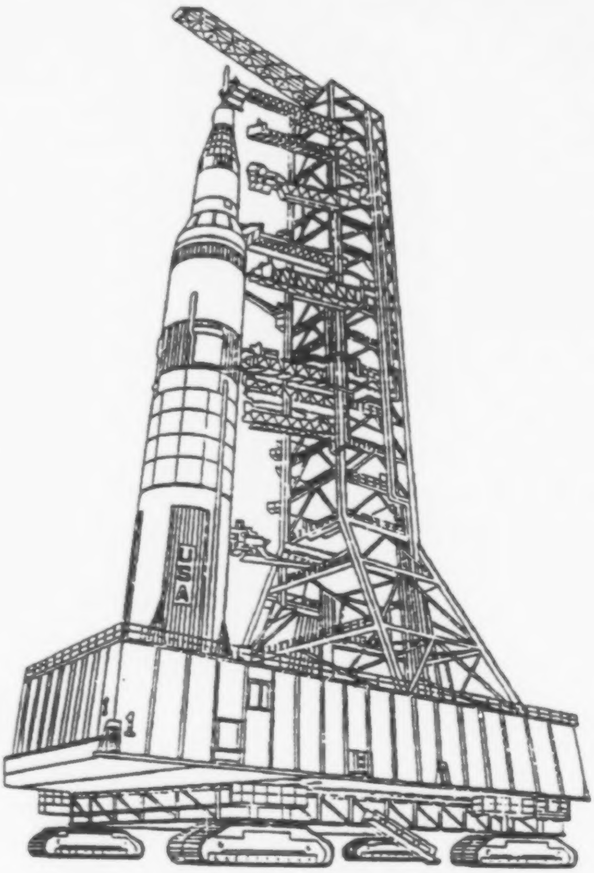


4. Try other combinations for simultaneous firings of the rockets such as a small amount of water in one and a larger amount of water in the other or equal amounts of water in one but pumped differently. Be sure to change only one variable at a time (ie. vary only the water or only the pumping).

DISCUSSION:

Isaac Newton's second law of motion states that *force is equal to mass times acceleration*. In rockets terms, it means that the thrust of a rocket is equal to the amount of mass (fire, smoke or steam, and gas) expelled by the rocket engine times how fast it is expelled. Designers of powerful rockets try to maximize both mass and acceleration to get the greatest thrust possible because thrust is a product of the two. In the 1960s, designers of the Saturn V rocket built first stage engines that burned kerosene and liquid oxygen. The two propellants were injected into each of the five engines of the first stage by high-speed turbines. Kerosene was chosen as the fuel because it is a very dense liquid when compared to other rocket fuels. During operation, the five engines consumed 15 tons of propellants per second. The combination of dense fuel and high-speed combustion produced a liftoff thrust of 7.5 million pounds.

Water rockets can demonstrate Newton's second law by varying the pressure inside the rocket and the amount of water present. In the first test, neither rocket went very far because the air inside did not have much mass. The rocket that was pumped more did travel farther because the air in that rocket was under greater pressure and it escaped the rocket at a higher speed (acceleration). When water was added to one of the rockets, the effect of mass was demonstrated. Before the air could leave the water rocket, the water had to be expelled first. Water has a much greater mass than air and it contributed to a much greater thrust. The rocket with water flew much farther than the rocket filled only with air. By varying the amount of water and air in the rocket and measuring how far the rockets travel, students can see that the thrust of the rocket is dependent on the mass being expelled and how fast it is being expelled. Thrust is greatest when mass and acceleration are greatest.



Saturn V Rocket

Classroom Activities

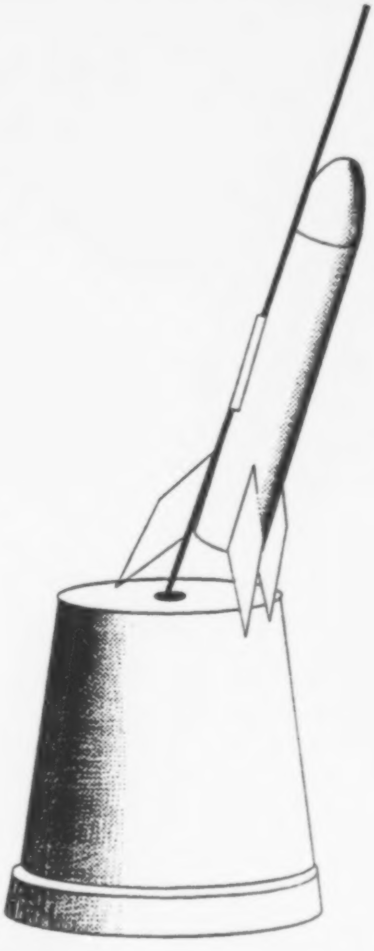
Flower Pot Launch Pad

Subject: Rocketry
Topic: Model rocket launch pad
Description: An inexpensive and versatile model rocket launch pad can be quickly assembled out of simple materials.
Contributed By: Norman O. Poff, OSU

Materials:
4 or 6 inch clay flower pot
Launch rod (model rocket suppliers) or heavy rod 1/8" by 36"

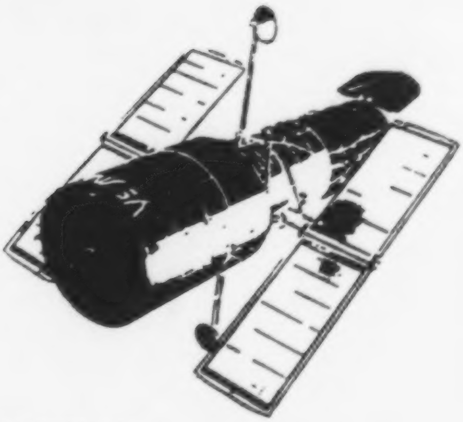
Procedure:

1. Select a wide and open field for a launch site. In general, the width of the field should be as great as the altitude you anticipate the rockets to reach in flight. The field should be away from power lines and other hazards.
2. Clear at least a 2 to 3 foot circle of burnable materials such as grass and leaves.
3. Invert the flower pot in the middle of the clear circle.
4. Slide the launch rod through the flower pot bottom hole and push it a short distance into the ground to anchor it. The upper end of the rod should be aimed into the prevailing wind so that returning rockets will land near the launch site. The launch pad is ready to use.



Discussion:
The clay flower pot provides an inexpensive fire proof launch platform. In addition, the bottom hole provides support for the rod and permits "heavy" rockets to be used. Adjustment of the launch rod for changing wind conditions is simply a matter of pulling out the rod and reinserting it into the ground.

NASA Hubble Space Telescope Model



NASA's Hubble Space Telescope opens new vistas to the Universe. Orbiting high above the filtering effects of Earth's atmosphere, the 240-centimeter-diameter (94-inch) mirror permits astronomers to see objects many times fainter and farther away than is possible with telescopes on the ground. The Hubble Space Telescope is designed to operate many years in space with only periodic servicing by Space Shuttle crews.

Instructions:

The plans below will permit you to construct a detailed model of NASA's Hubble Space Telescope at an approximate scale of 1:70. The following is a list of materials and tools needed for the model:

Sharp paper scissors
Razor blade
Sharp punch (such as an ice pick or nail)
Glue stick, white school paste, or contact cement
Cellophane tape

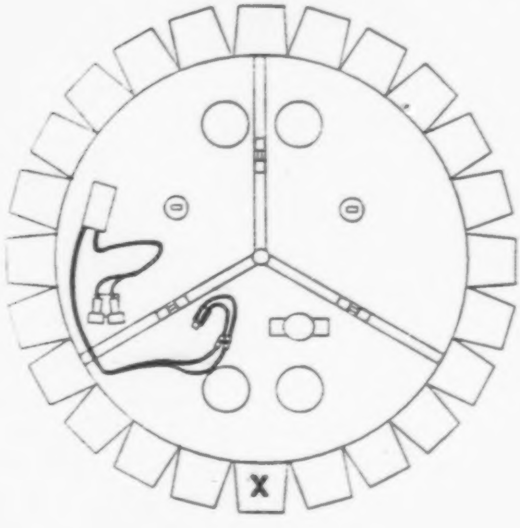
2X2 inch square piece of aluminum foil
2 7.5-inch pieces of 1/8 inch dowel rods
Colored sharp point marker pens (yellow and red)
Blue highlighter pen
Orange highlighter pen

* Before cutting out the pieces, use marker pens to color structures on the model as indicated.

#1 Assembling the AFT SHROUD

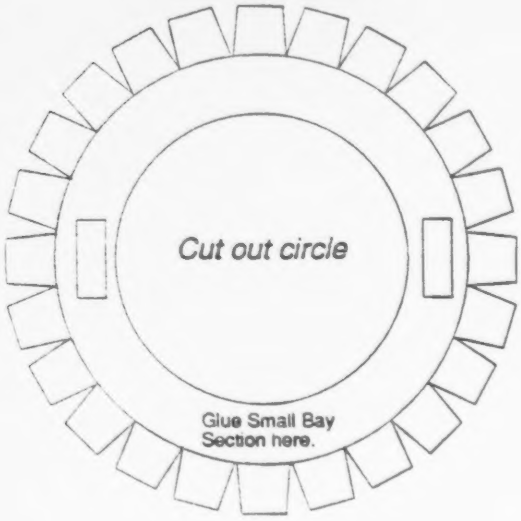
1. Carefully cut out the following pieces: AFT SHROUD cylinder, End Cap, and the INNER RING. Use the razor blade to cut small slits for insertion of the assembly tabs of the cylinder.
2. Shape the AFT SHROUD cylinder by curling the paper around the edge of a table or desk. This will permit the paper to be easily rolled into a cylinder.
3. Curl the paper to form a tube and insert the tabs of the cylinder into the slits cut in step 1. Hold the cylinder together with a piece of tape pressed to the inside.
4. Fold the tabs of the INNER RING downward. Coat each tab with glue and lay the ring upside down on a flat surface. Place the cylinder over the inner ring so that all tabs are inside. The seam of the cylinder should align with the word "SMALL" on the INNER RING. Reach in with a finger and press each tab to the inside wall of the cylinder. You will need to support the outer wall of the cylinder with another finger to achieve a good bond.
5. Fold the tabs of the END CAP downward and coat each with glue. Place the end cap upside down on a flat surface and place the other end of the cylinder over it. Align the "X" with the seam Press the tabs in place. If you have trouble reaching the tabs, use the erasure end of a pencil in place of your finger.
6. The AFT SHROUD is completed. Set it aside.

END CAP

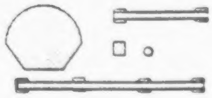


Created by Gregory Vogt, AESP, OSU - 2/90

INNER RING


Cut out circle
Glue Small Bay Section here.

Color these features yellow →



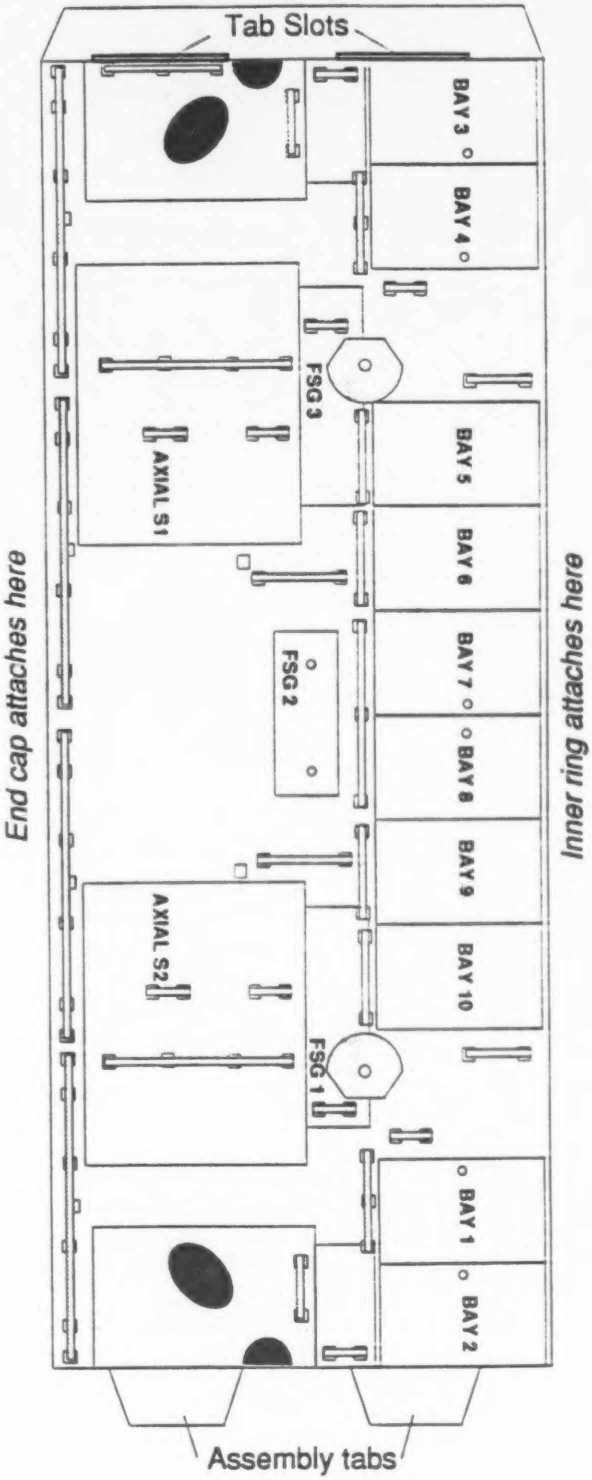
#2 Assembling the FORWARD SHELL and LIGHT SHIELD

1. Carefully cut out the FORWARD SHELL and LIGHT SHIELD assembly. Use the razor blade to cut the slits for the insertion of the assembly tab.
2. Shape the tube by pulling the paper over the edge of a table or desk.
3. Curl the paper to form a tube and insert the tabs into the slit. Use tape inside the tube to hold it together.

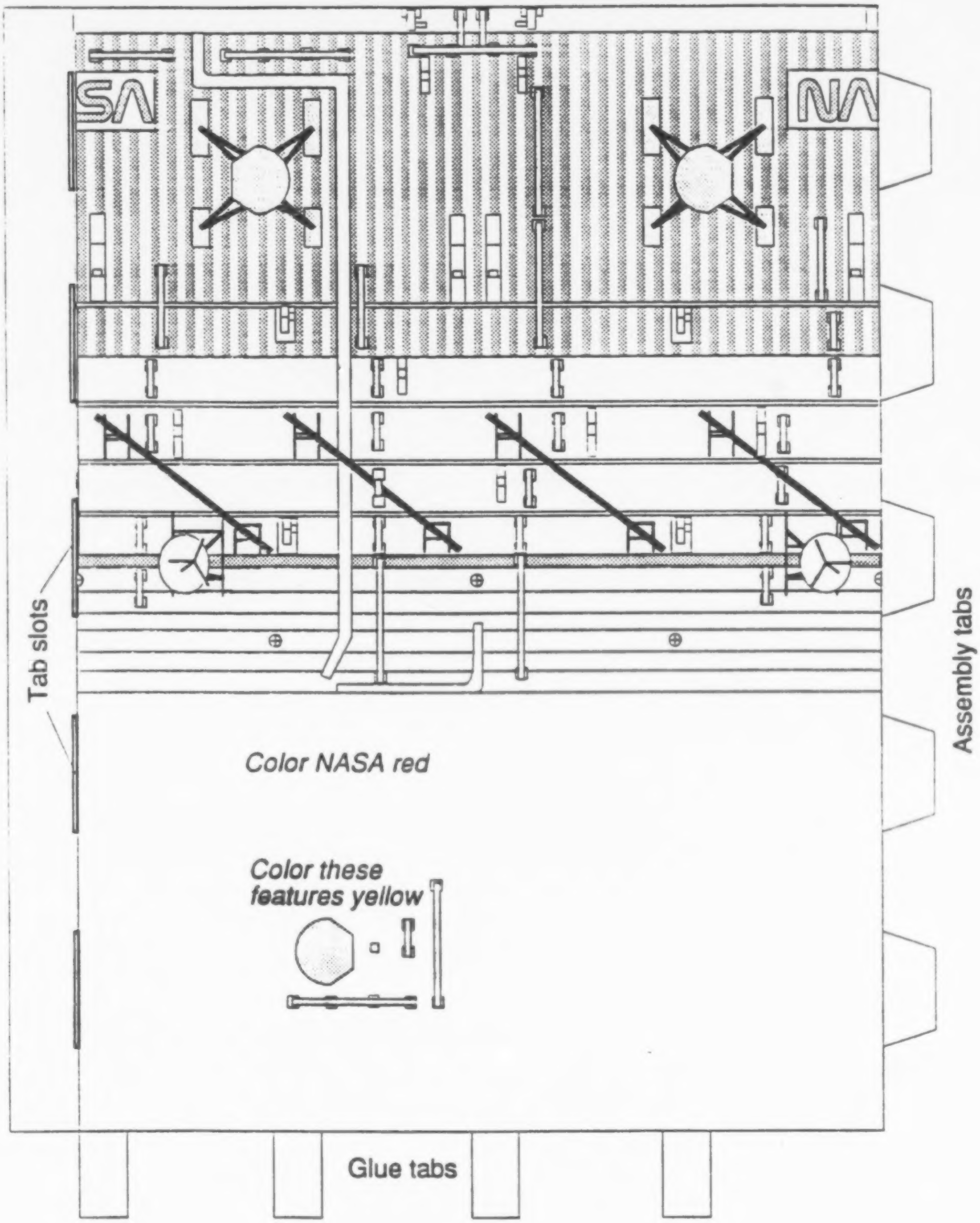
#3 Joining the AFT SHROUD and the FORWARD SHELL and LIGHT SHIELD

1. Bend the four glue tabs at the lower end of the FORWARD SHELL and LIGHT SHIELD inward and cover with glue.
2. Place the AFT SHROUD on a flat surface with the inner ring pointed up. Insert the FORWARD-SHELL and LIGHT SHIELD with the glue tab end down. Align the seam of the two cylinders.
3. Make sure the FORWARD SHELL and LIGHT SHIELD is standing straight up. Use a long piece of dowel rod to reach inside the tube and press the tabs to the end cap so that they will bond to the inside of the END CAP.

AFT SHROUD


Tab Slots
BAY 3
BAY 4
FSG 3
AXIAL S1
BAY 5
BAY 6
BAY 7
BAY 8
BAY 9
BAY 10
FSG 2
AXIAL S2
FSG 1
BAY 1
BAY 2
End cap attaches here
Inner ring attaches here
Assembly tabs

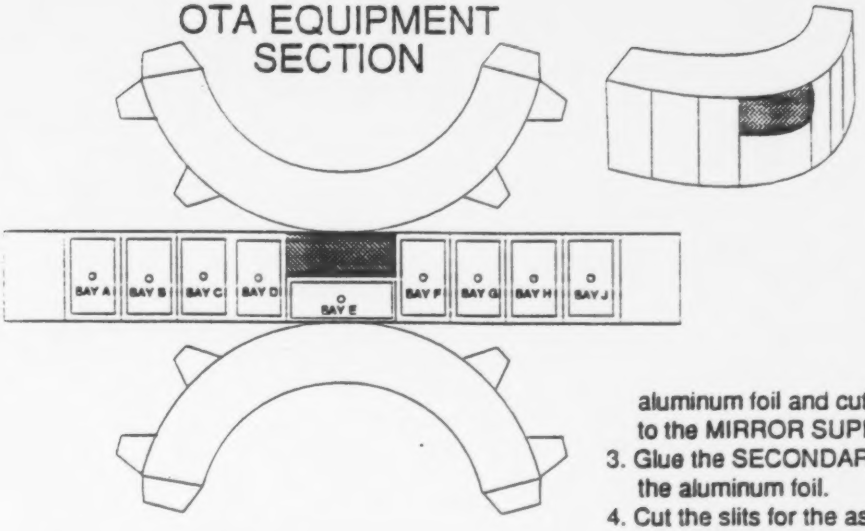
FORWARD SHELL AND LIGHT SHIELD


SA
NA
Tab slots
Assembly tabs
Color NASA red
Color these features yellow
Glue tabs

#4 Assembling the OTA EQUIPMENT SECTION

1. Carefully cut out the OTA EQUIPMENT SECTION.
2. Curl the bay section to form a semicircle.
3. Fold the glue tabs downward and the curved sections downward.
4. Apply glue to the tabs and join the segments as indicated in the diagram.

OTA EQUIPMENT SECTION



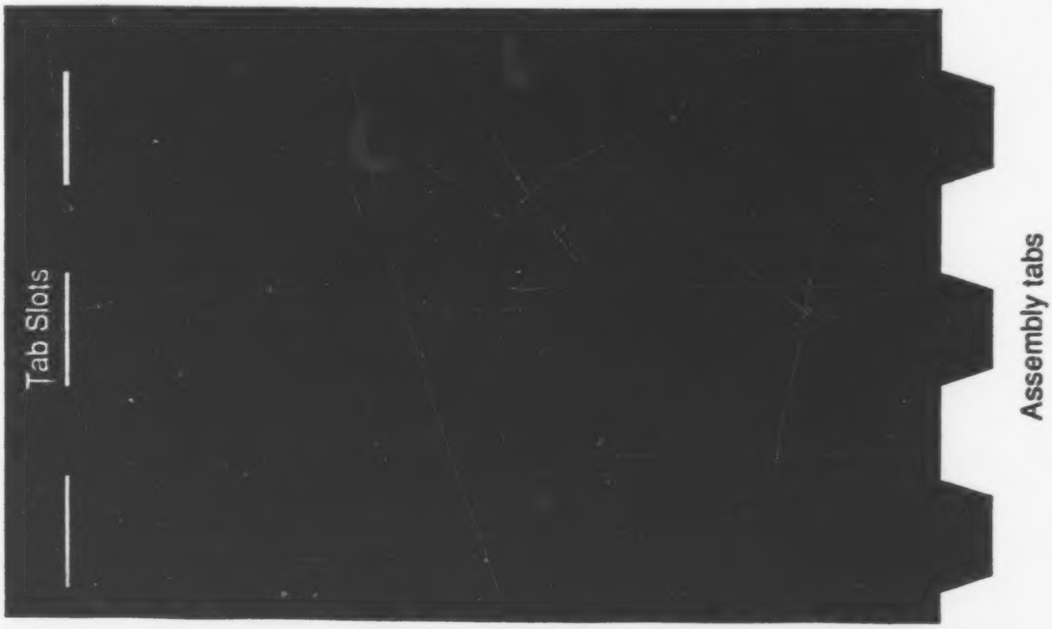
#5 Joining the OTA EQUIPMENT SECTION to the AFT SHROUD

1. Apply glue to the OTA EQUIPMENT SECTION where indicated.
2. Press the OTA EQUIPMENT SECTION to the INNER RING where indicated.

#6 Assembling the BARREL INSERT

1. Cut out the BARREL INSERT, MIRROR SUPPORT, and SECONDARY MIRROR SUPPORT.
2. Trace the circle of the MIRROR SUPPORT on the aluminum foil and cut out the circle. Glue the foil to the MIRROR SUPPORT.
3. Glue the SECONDARY MIRROR SUPPORT on to the aluminum foil.
4. Cut the slits for the assembly tabs on the BARREL INSERT. Curl the paper to form a tube by dragging it over the edge of a table or desk.
5. Form the BARREL INSERT by rolling the paper, with the black side inward, and inserting the tabs into the slits from the inside. Hold the tube together by applying tape to the outside.
6. Fold the glue tabs of the MIRROR SUPPORT inward toward the foil side. Coat the tabs with glue. Bond the MIRROR SUPPORT to the end of the BARREL INSERT with the glue tabs to the outside.

BARREL INSERT



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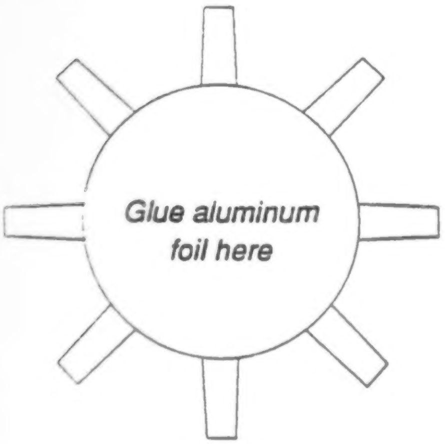
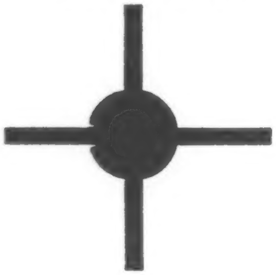
MIRROR SUPPORT



SECONDARY MIRROR SUPPORT



#7 Joining the APERTURE DOOR to the BARREL INSERT

1. Cut out the APERTURE DOOR.
2. Apply glue to the back side of the middle glue tab and to the front side of the remaining two tabs.
3. Spread the glue tabs and attach the APERTURE DOOR to one end of the BARREL INSERT at the seam. The middle tab should be on the inside and the other tabs on the outside. Press the tabs to the tube.

#8 Inserting the SOLAR ARRAY and ANTENNA rods

1. Use the punch to make four small holes in the side of the FORWARD SHELL and LIGHT SHIELD at the places indicated. Look for this symbol — ⊕
2. Carefully insert the two dowel rods into the holes so that each extends through to the opposite side.

#9 Assembling the SOLAR ARRAYS

1. Cut out each SOLAR ARRAY.
2. Coat the inside of the front array with glue and join it to its matching back side. When doing so, place the pieces over the ends of the solar array dowel rod. The glue will hold the arrays to the rod.

#10 Assembling the ANTENNAS

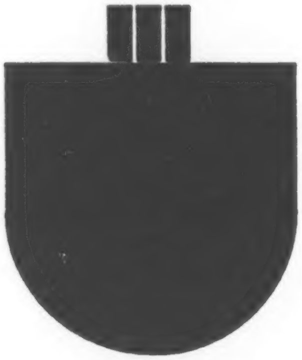
1. Cut out the ANTENNA circles.
2. Glue the front of each antenna to the back. When doing so, place the pieces over the ends of the solar array dowel rod. The glue will hold the arrays to the rod.

#11 Inserting the BARREL INSERT

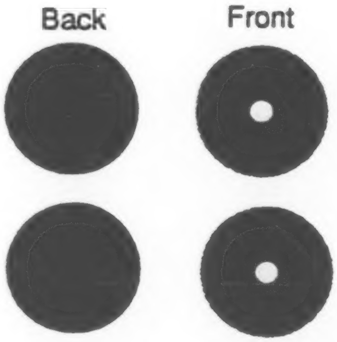
1. Insert the BARREL INSERT into the FORWARD SHELL AND LIGHT SHIELD so that the APERATURE DOOR is opposite the seam of the cylinder.

The NASA Hubble Space Telescope Model is now complete. You can display it by suspending it from the ceiling by a piece of thread or monofilament fishing line or create a base for it.

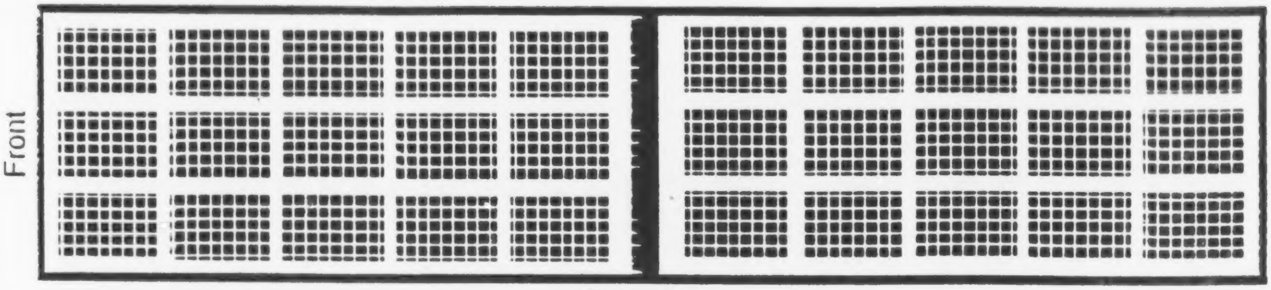
APERTURE DOOR



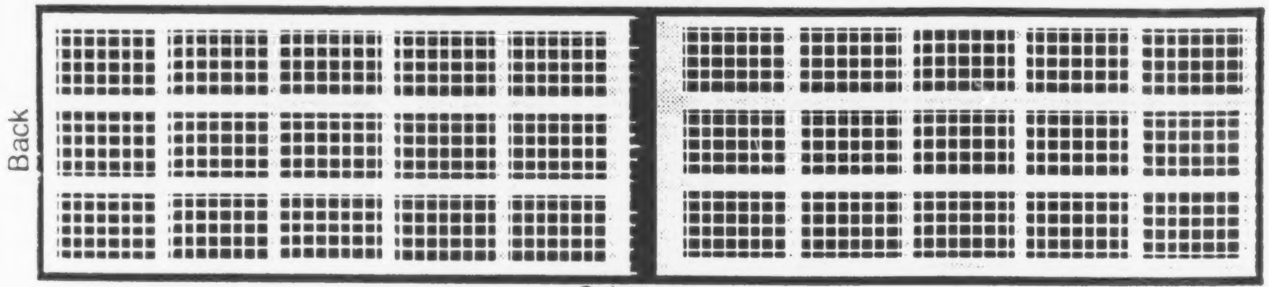
ANTENNAS



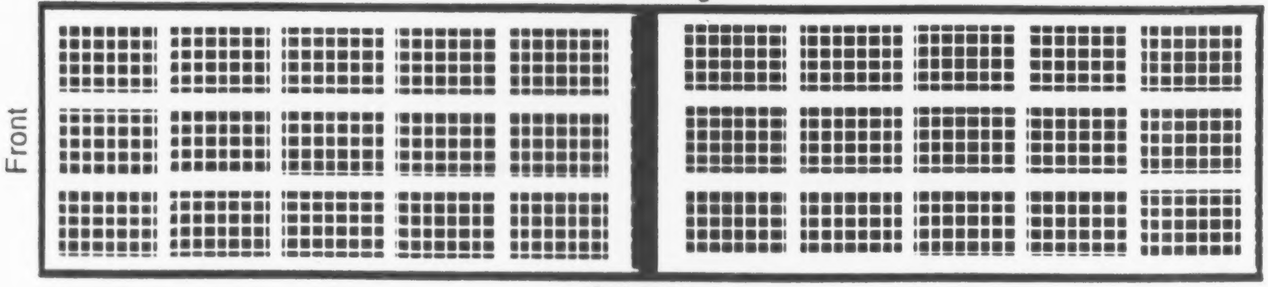
SOLAR ARRAYS



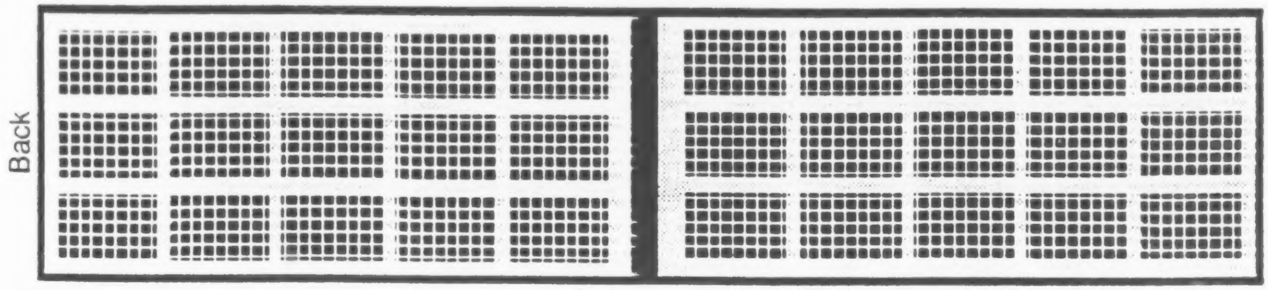
Color blue



Color orange

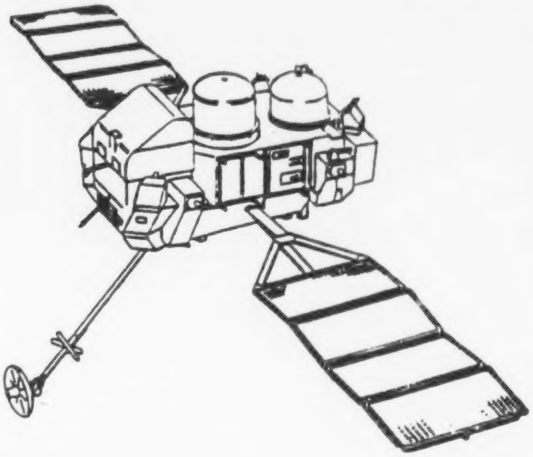


Color blue



Color orange

NASA Gamma Ray Observatory Model



The Gamma Ray Observatory is the second in a great observatory series NASA plans to launch. The first is the Hubble Space Telescope that was orbited in 1990. Astronomers around the world are eager for the data the spacecraft will provide because it will help them to fill in missing pieces in our view of the universe about us. Outer space is filled with electromagnetic radiation that tells the story of the birth and death of stars and galaxies. Only a small portion of that radiation is visible to our eyes. The rest can be detected only with special instruments. Gamma rays are one form of invisible radiation. In a chart of the electromagnetic spectrum, gamma rays fall at the far right end after visible light, ultraviolet light, and X rays. Gamma rays have very short wavelengths and are extremely energetic, but most of them do not penetrate Earth's atmosphere. The only way for astronomers to view these waves is to send instruments into space.

The GRO is a complex spacecraft fitted with four different gamma ray detectors, each of which concentrates on different but overlapping energy ranges. The instruments are the largest of their kind that have ever flown in space. This is important because gamma rays can only be detected when they interact with matter. The bigger the masses of the detectors, the greater the number of gamma rays they can detect. The process for gamma ray detection is similar to the way fluorescent paints convert ultraviolet light to visible light. When gamma rays interact with crystals, liquids, and other materials, they produce flashes of light that are recorded by electronic sensors. Astronomers can determine how energetic a particular ray is from the intensity of the flash. The brighter the flash of light from the interaction, the higher the energy of the ray.

The four different kinds of gamma ray detectors on the GRO are the Burst and Transient Source Experiment (BATSE), Oriented Scintillation Spectrometer Experiment (OSSE), Imaging Compton Telescope (COMPTEL), and the Energetic Gamma Ray Experiment Telescope (EGRET). The BATSE experiment consists of eight detectors placed on the corners of the spacecraft. The other experiments consist of single devices.

Astronomers will compare the intensities and directions of gamma ray interactions with the GRO's detectors to learn about the most powerful celestial bodies and events in the universe. The GRO will help astronomers address fundamental questions about the process of energy transfer in the universe and provide a new understanding of the processes at work in supernovas, neutron stars, pulsars, and quasars.

Instructions:

The plans that follow will permit you to construct a detailed model of the Gamma Ray Observatory spacecraft. The following is a list of materials and tools you will need for the model:

Sharp paper scissors
Razor blade knife
Straight edge
Sharp punch (such as an ice pick)
Rubber cement
Cutting surface (such as wood board)
Silver paint marker or grey marker pen
Blue marker pen
Yellow marker pen
Dowel rod (1/16 inch)

General Tips

- Several model pieces require small holes to be punched through them. ⊕ Punch the holes before cutting out the pieces. Also cut out the centers of the slots for assembly tabs.
- Carefully cut out each part from the plans along the solid exterior lines.
- Using the razor blade knife, lightly score all fold lines to make accurate folds possible. Fold lines are dashed. Also score the lines for the glue tabs.
- Test all folds to make sure they are accurate before applying cement.
- Color model pieces where indicated before applying glue.
- To achieve good glue bonds, apply rubber cement to the shaded glue tabs in the areas indicated and to the opposite side of the model part where the glue tabs join. Double coating the glue before joining provides the strongest bonds.
- After assembling the model pieces, lightly rub away any excess glue.
- Assemble the spacecraft bus first and insert all other parts into it.

#1 Assembling the Bus

1. Be sure to punch out the holes for the solar array rod out of the side of the bus and cut out the holes for the OSSE, COMPTEL, and EGRET.
2. This component is easiest to assemble by joining edge A to edge B. Follow with the assembly of the ends.
3. Try to keep joints square at all times and smooth out any curves that might be produced.

#2 Assembling the Propellant Tanks

1. After forming this part, slip the four assembly tabs into the four slots in the bottom of the Bus.

#3 Assembling the cradles

1. Punch out the two holes indicated in the OSSE cradle.
2. Begin joining each of the cradles with the glue tabs nearest the center folds. Continue joining segments, in order, to the upper ends of the "U" shape.
3. Slide the cradles into their proper positions on the bus. To make this easier, bend the assembly tabs upward and gently push them into the corresponding slots. The tip of the razor blade knife can be used to assist in the insertion.
4. To provide extra strength to the model, it is recommended that the surfaces of the cradles and the propellant tanks that touch be glued together.

#4 Assembling the COMPTEL and EGRET

1. After forming the two domes, slide them inside the corresponding cylinders from the bottom. The domes should protrude but the overlapping glue tabs should remain inside the cylinders.
2. Slip each cylinder in the proper hole in the bus. To make this easier, bend the assembly tabs on the bus upward and slip them into the cylinder slots as they are pushed downward. For a better looking model have the cylinder seams face each other.

#5 Assembling the OSSE

1. It is easiest to assemble this part by folding around the curve before folding in the bottom.

#6 Assembling the BATSE

1. Score the fold lines before cutting out the pieces. After making all eight BATSE pieces, glue each to the model in the places indicated in the completed model diagram.

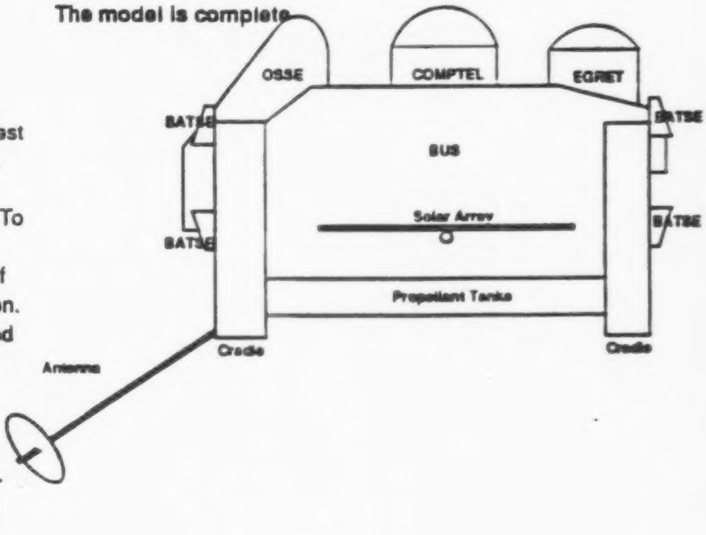
#7 Assembling the Solar Arrays

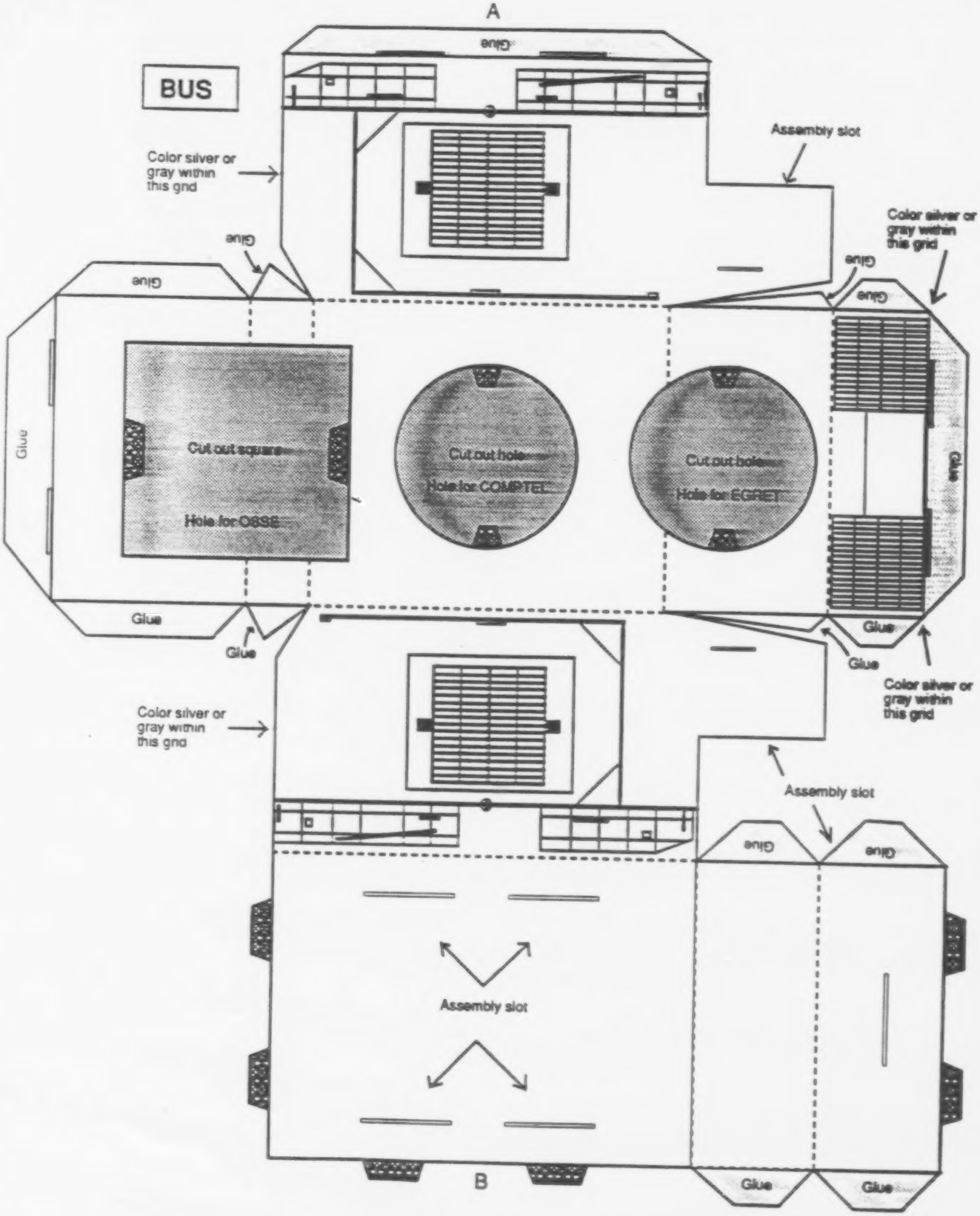
1. Be sure to punch the holes indicated in each array before cutting them out.
2. Coat the back side of each array with glue and fold them together along the dashed fold lines.
3. Cut one piece of dowel rod 45-cm long.
4. Slip the rod through the holes in the bus.
5. Carefully slide each array on the rod by passing the rod through the holes on the arrays.

#8 Assembling the Antenna

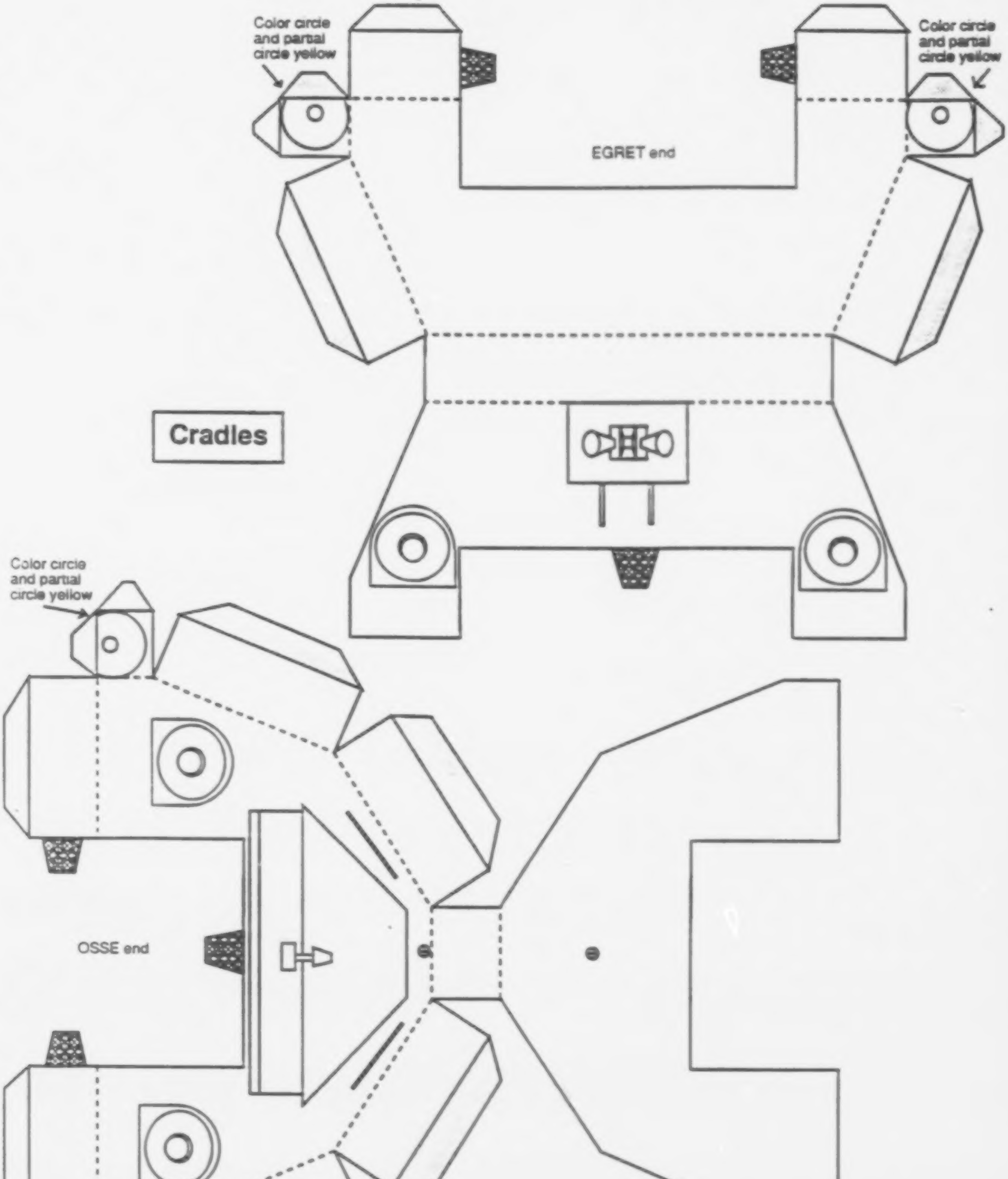
1. Cut out both forms. Be sure to punch the holes first.
2. Curl the large form onto itself to form a shallow cone.
3. Coat the inside of the center of the cone and the back side of the smaller circle with glue. When dry, press the smaller circle into the center of the cone.
4. Cut a 14-cm piece from the remaining dowel rod. Slide the antenna on to one end of the rod. Slip the other end of the rod through the holes in the bottom of the cradle on the OSSE end of the spacecraft.

The model is complete




A
BUS
Glue
Color silver or gray within this grid
Assembly slot
Glue
Glue
Glue
Color silver or gray within this grid
Glue
Glue
Cut out square
Hole for OSSE
Cut out hole
Hole for COMPTEL
Cut out hole
Hole for EGRET
Glue
Glue
Glue
Glue
Glue
Glue
Color silver or gray within this grid
Color silver or gray within this grid
Assembly slot
Assembly slot
Glue
Glue
Assembly slot
B
Glue
Glue

Cradles

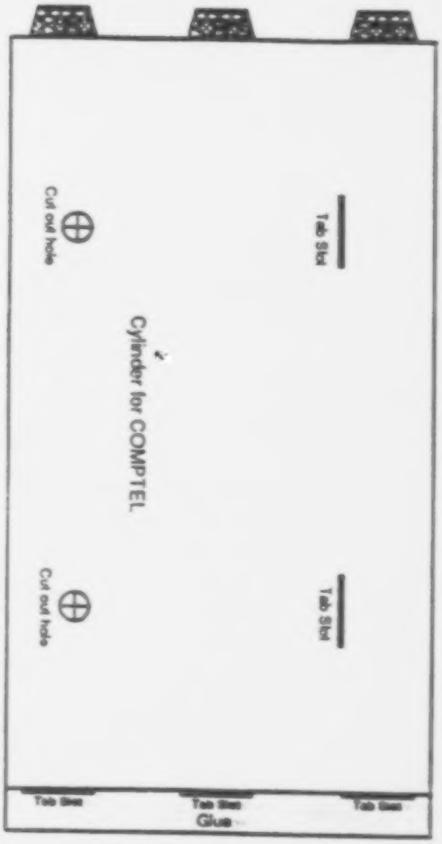


Color circle and partial circle yellow

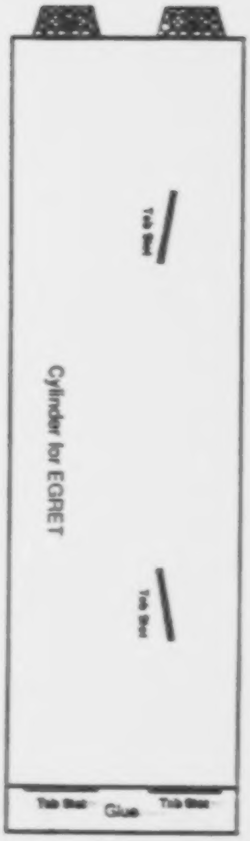
Color circle and partial circle yellow

Color circle and partial circle yellow

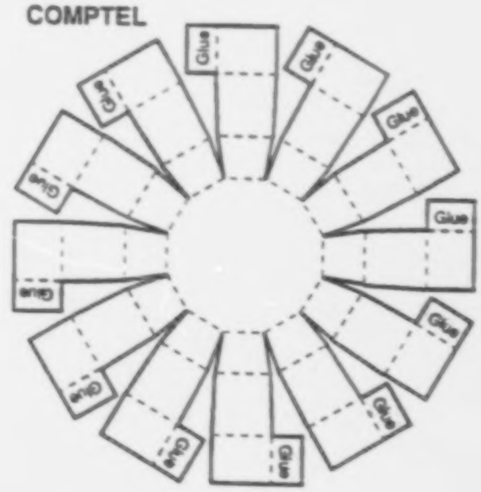
Color circle and partial circle yellow


Tab Slot
Cut out hole
Cylinder for COMPTEL
Tab Slot
Cut out hole
Tab Slot
Tab Slot
Tab Slot
Glue

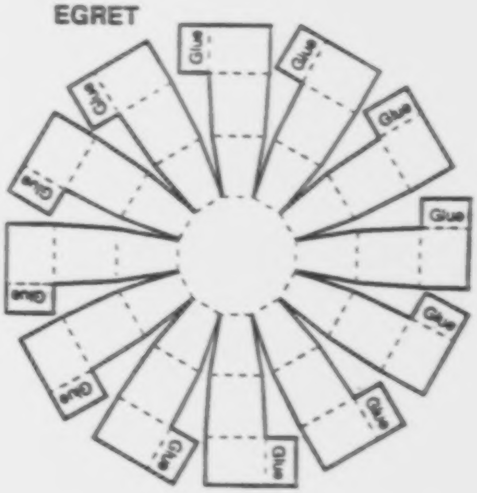
COMPTEL
EGRET


Tab Slot
Cylinder for EGRET
Tab Slot
Tab Slot
Glue
Tab Slot

COMPTEL

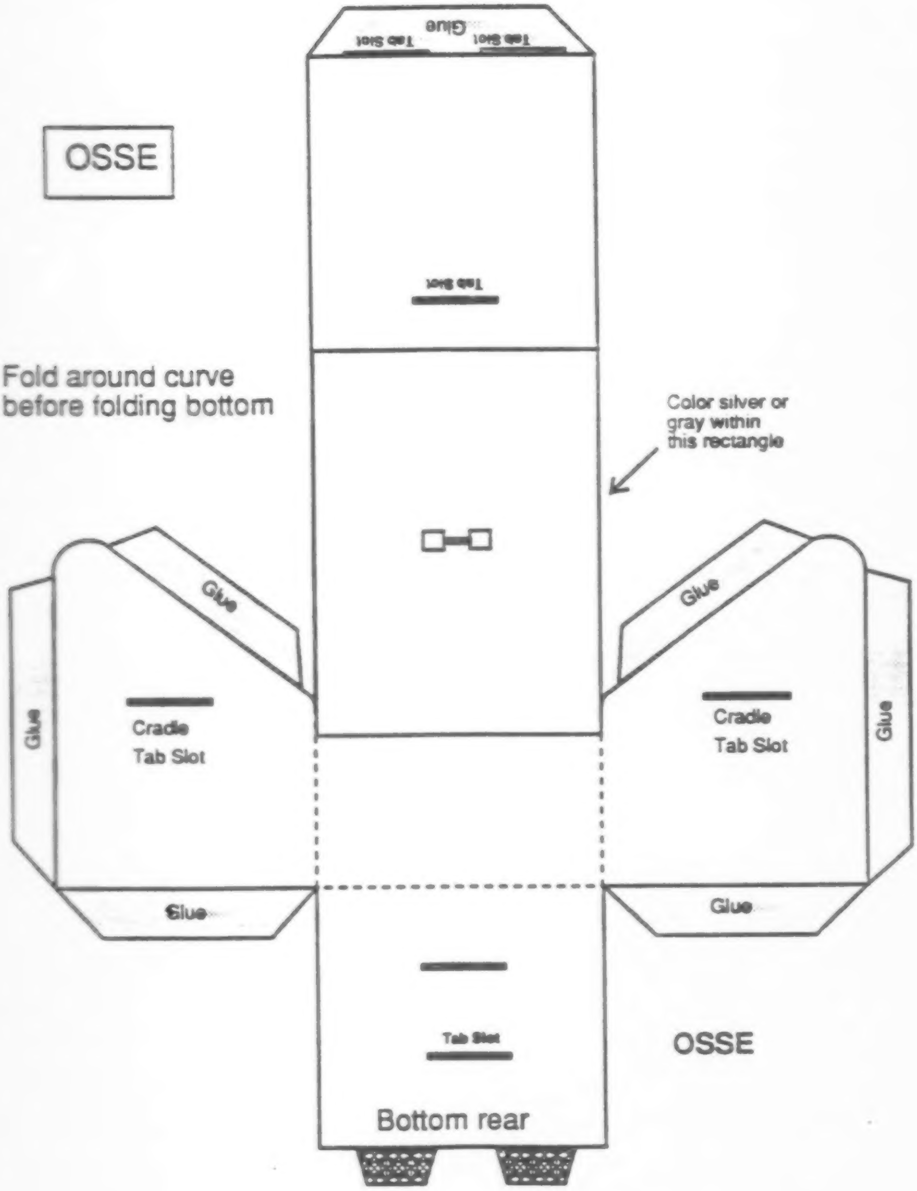

Glue
Glue
Glue
Glue
Glue
Glue
Glue
Glue
Glue
Glue
Glue
Glue

EGRET


Glue
Glue
Glue
Glue
Glue
Glue
Glue
Glue
Glue
Glue
Glue
Glue

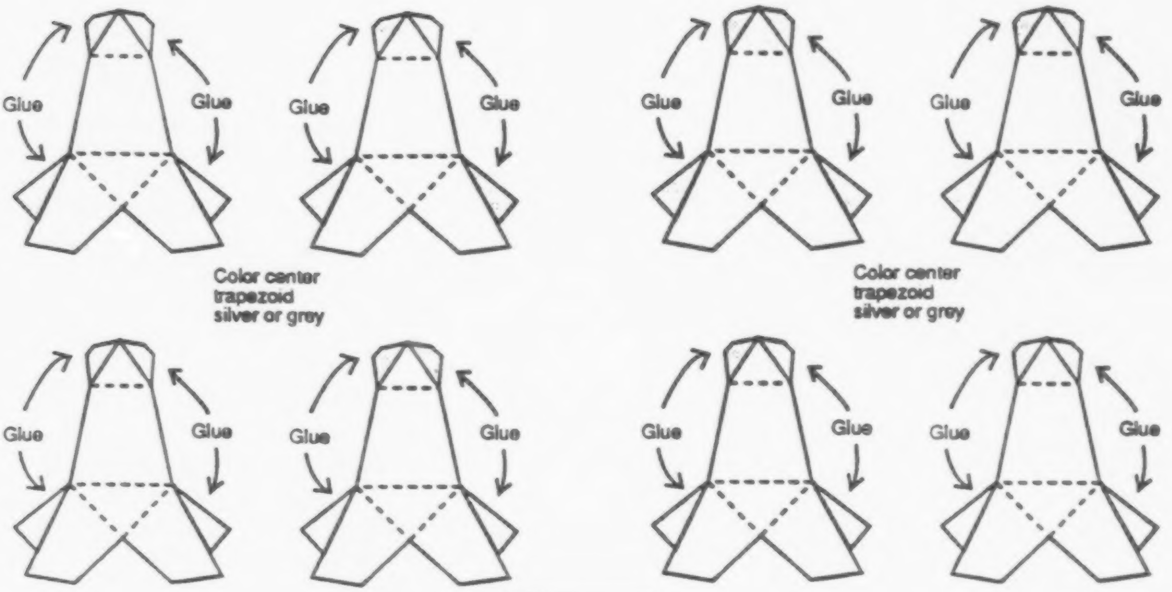
OSSE

Fold around curve before folding bottom


Tab Slot
Glue
Tab Slot
Tab Slot
Glue
Glue
Cradle Tab Slot
Glue
Glue
Cradle Tab Slot
Glue
Glue
Tab Slot
Bottom rear

Color silver or gray within this rectangle

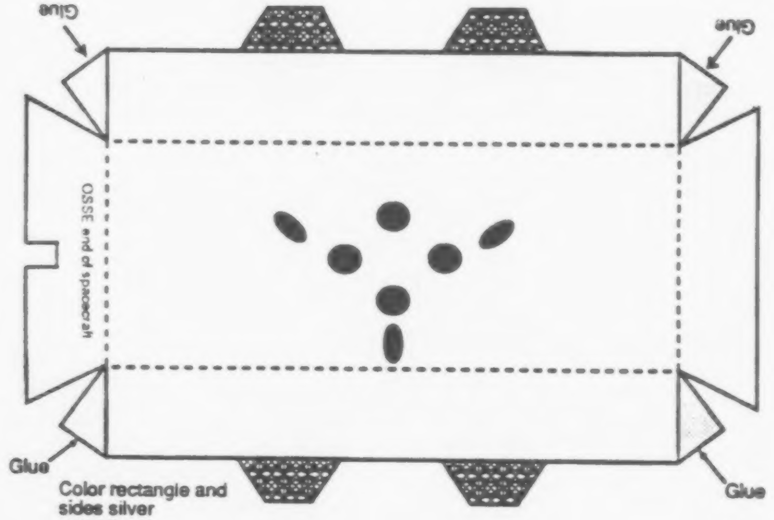
OSSE


Glue
Glue
Glue
Glue
Glue
Glue
Glue
Glue
Glue
Glue
Glue
Glue
Glue
Glue
Glue
Glue

Color center
trapezoid
silver or grey

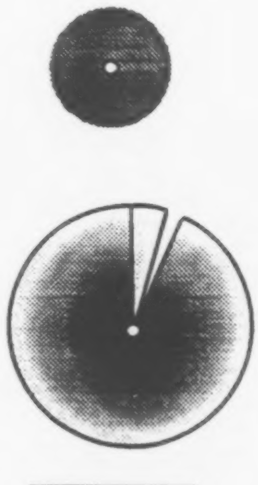
Color center
trapezoid
silver or grey

BATSE

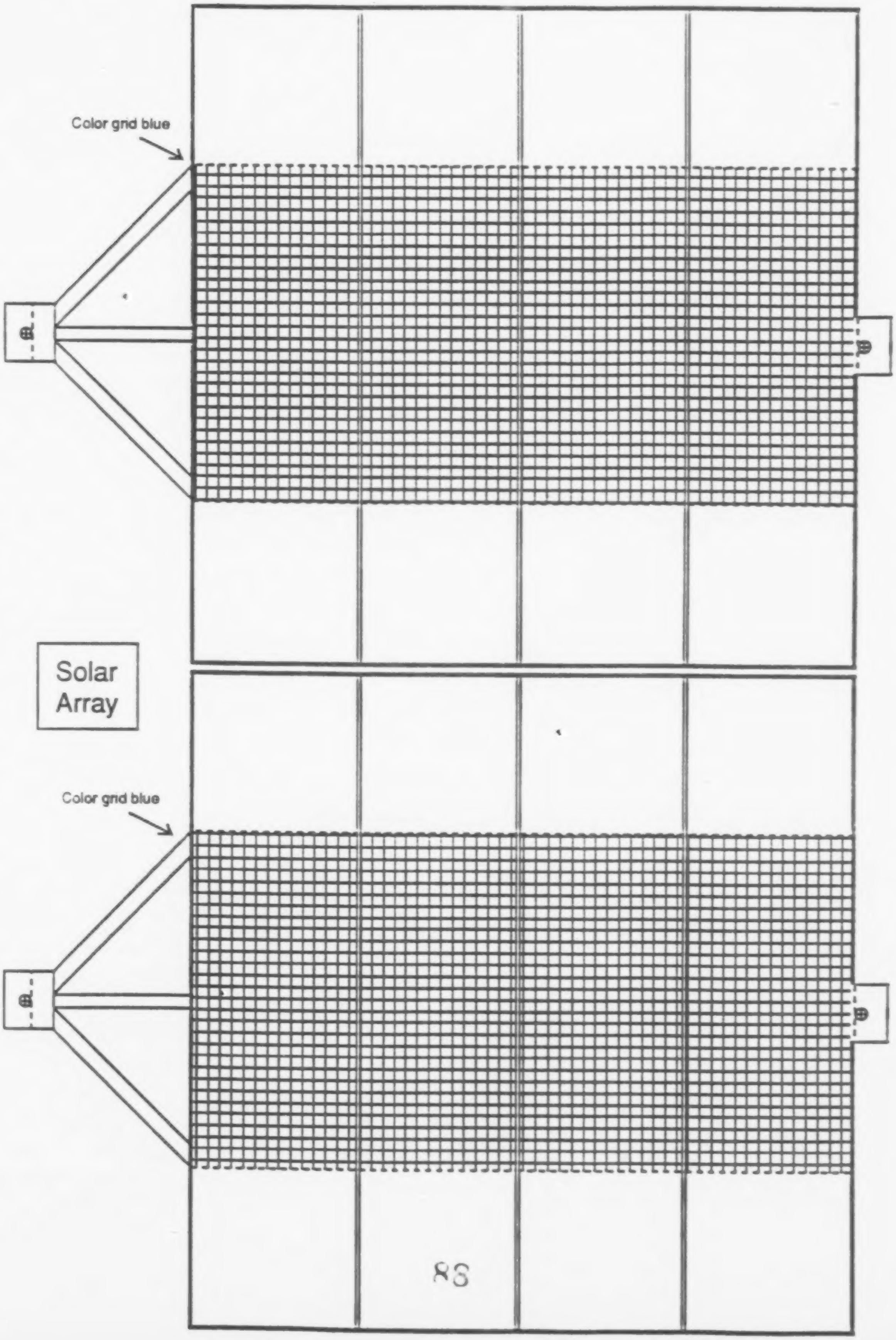

Glue
Glue
OSSE end of spacecraft
Glue
Glue

Color rectangle and
sides silver
or grey

Propellant Tanks



Antenna

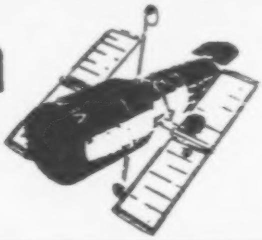


Solar Array

Color grid blue

Color grid blue

Classroom Activities



Magic Wand

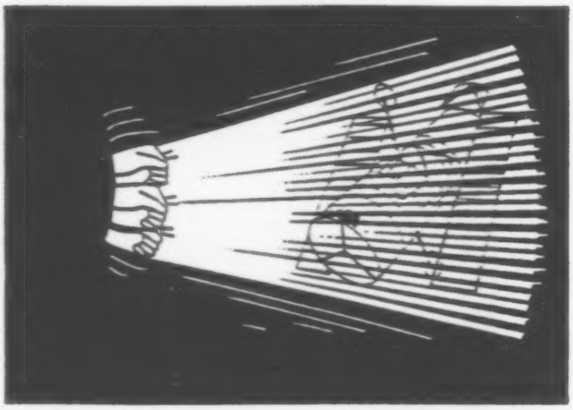
Subject: Pictures from space
Topic: Imaging
Description: A recognizable image from a slide projector appears on a white rod that is rapidly moved across the projector's beam.
Contributed By: Based on an exhibit from the Exploratorium

Materials:

- Slide projector
- Color slide of clearly-defined object such as Saturn, a building, people, etc.
- Dowel rod
- Sheet of white paper
- White paint (flat finish)
- Dark room

Procedure:

1. Paint the dowel rod white and permit it to dry.
2. Set up the slide projector in a dark room and focus the image of the slide at a distance of about 10 feet. Hold up the sheet of paper in the beam at the proper distance for focusing. Be sure the focus point is in the middle of the room. If it is near a wall, the image will be easy to make out.
3. While holding the dowel rod in one hand, slowly move it up and down perpendicular to the projector beam at the focus distance. Ask the students to try to make out what the picture is.



4. Gradually, increase the speed of the rod's movement.
5. When the rod moves very fast, the image becomes very clear.

Discussion:

NASA's Hubble Space Telescope will remain for years in space capturing light from distance objects and radioing images to Earth. The images are transmitted bit by bit in numerical form to waiting computers that store the data and interpret the binary numbers used to reassemble the images.

This activity roughly demonstrates the imaging process used by the

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Hubble Space Telescope. By slowly moving the rod across the slide projector's beam, small fragments of the image are captured and reflected ("radioed") towards the students. Because the fragments are quickly forgotten, the addition of many more fragments, as the rod continues to move, confuse the image in the student's mind. However, as the rod is moved more rapidly, an important property of the eye comes into play. Light images are momentarily retained on the retina of the eye. This property is called *persistence of vision*. As the rod is moved rapidly, each image fragment remains just long enough to combine with the others to form a recognizable image. In this activity, the eye is an analogy of the imaging processing computer that stores numerical image fragments, collected and radioed to Earth by the Hubble Space Telescope, and reassembles them for use.